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Fiscal Policy in Classical and Keynesian Open Economies

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In this model of classical and Keynesian open economies, both permanent and transitory disturbances cause changes in long-run output and capacity — and transitory and permanent shocks may have opposite effects on the current account. In the Keynesian economy, money-financed fiscal expansion causes real exchange rate depreciation; and non-money-financed fiscal expansion, appreciation.

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Summary findings

Schmidt-Hebbel and Serven analyze the impact of fiscal policy changes in open economies, using a rational-expectations framework that nests two prototype economies: a neoclassical full-employment benchmark economy, with intertemporally optimizing consumers and firms and instant clearing of asset, goods, and factor markets; and a Keynesian economy, with liquidity constraints and wage rigidity, which results in transitory deviations from full employment.

The model is forward-looking in that the economy's short-run equilibrium depends on current and anticipated future values of all exogenous variables, and displays hysteresis (that is, its long-run equilibrium is path-dependent).

Using parameters for a representative open economy, the model is simulated to compare the dynamic effects of increases in public spending financed by taxation, debt, and money. The results illustrate four points:

- Both permanent *and* transitory disturbances cause changes in long-run output and capacity.
- Transitory and permanent shocks may have opposite effects on the current account.
- Liquidity constraints and wage rigidities tend to amplify the cyclical adjustment to fiscal policy changes.
- The Keynesian economy's response to fiscal shocks depends critically on the way the budget is financed: money-financed fiscal expansion causes real ***depreciation;*** non-money-financed fiscal expansion causes ***appreciation.***

This paper — a product of the Macroeconomics and Growth Division, Policy Research Department — is part of a larger effort in the department to model macroeconomic adjustment in open economies. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Emily Khine, room N11-061, extension 37471 (47 pages). May 1994.

FISCAL POLICY IN CLASSICAL AND KEYNESIAN OPEN ECONOMIES*

by

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The World Bank

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1. INTRODUCTION

A bewildering variety of macroeconomic tools is available today to macroeconomic policy makers and analysts. The model developed here forms part of a small but growing sub-family of macroeconomic frameworks which, while firmly based on microanalytic foundations, introduce critical real-world features -- such as short-run wage rigidities and liquidity constraints -- which generate persistent deviations from the frictionless full-employment outcome of the unconstrained neoclassical paradigm. The dynamic general equilibrium model developed here nests as special cases a classical and a Keynesian benchmark, and assumes rational expectation formation. Hence short-term equilibria depend on current and anticipated future trajectories of policy and external variables.

Forward-looking behavior based on microanalytical foundations is a feature that this paper shares with an increasing number of recent models applied to open-economy issues such as oil shocks, interest rate changes or policy coordination in multi-country frameworks (Sachs, 1983; Giavazzi et.al., 1982; Lipton and Sachs, 1983; Bruno and Sachs, 1985; McKibbin and Sachs, 1989; McKibbin and Sundberg, 1990; McKibbin and Wilcoxen, 1992). Nesting of classical and Keynesian benchmarks characterizes also the model by McKibbin and Sachs (1989), although they do not discuss its implications for the response of the economy to shocks. This paper extends previous work in four dimensions. First it extends the analytical structure by incorporating simultaneously several realistic features that are relevant for most open economies: nominal wage rigidity, import content of capital goods, foreign holdings of domestic equity, public investment and monetary finance of budget deficits.[1] Second, it explores in some detail the short and long-term consequences of liquidity constraints affecting private consumption and investment behavior. Third, the paper compares the differential effects of external shocks in neoclassical and Keynesian benchmark economies, for both permanent/transitory and anticipated/unanticipated disturbances. Finally, the simulations are performed by solving the full non-linear model, in contrast with the conventional procedure that uses a linear approximation, whose accuracy can be highly unreliable when simulating "large" shocks. In related papers (Schmidt-Hebbel and Serven, 1994a,b), we use the same framework to analyze the dynamic adjustment of small open economies to external shocks (foreign transfers, terms-of-trade windfalls, and lower foreign interest rates).

The paper is organized as follows. Section 2 spells out the model structure, which is based on the distinction of the domestic private sector (households and firms), the consolidated public sector, and the external sector. The private sector comprises one group of intertemporally-optimizing agents with another of liquidity-constrained (or myopic) agents. The domestic economy produces one single good, while the rest of the world produces both an intermediate input and a final good; the three goods are imperfect substitutes. The asset menu distinguishes between foreign and domestic bonds, domestic equity, and domestic money. Asset markets, as well as the domestic goods market, are assumed to clear instantly. In contrast, the labor market can display real and/or nominal wage inertia, giving rise to persistent deviations from full employment.

Section 3 describes the steady state and the stability properties of the economy. The dynamics of the model are characterized by the combination of backward-looking dynamic equations describing the time paths of predetermined variables (asset stocks, as well as the real wage), and forward-looking equations describing the trajectory of asset prices. The model displays hysteresis and thus its steady state is path-dependent: it is affected by the initial conditions and the entire adjustment path followed by the

[1] Three of these features (wage rigidity, import content of capital goods, and foreign holdings of domestic equity) are considered in different forms by previous models, in particular McKibbin and Sachs (1989). Explicit inclusion of public investment and monetary finance of budget deficits are novel features of this framework.

economy in response to a shock. Transitory disturbances can therefore have permanent effects, whose magnitude depends on key parameters determining the speed of adjustment of the system. The numerical solution of the model poses a two-point boundary-value problem.

Section 4 presents simulation results for an increase in public consumption financed by lump-sum taxation (a balanced-budget expansion), debt, and money. The section discusses and compares the effects of the shock on the dynamic patterns of the main endogenous variables, for different combinations of structural benchmarks (neo-classical, and liquidity constraints with unemployment) and shock types (permanent, transitory unanticipated and transitory anticipated). Section 5 closes the paper with some concluding remarks.

2. THE MODEL

The domestic economy produces one single final good, which can be used for consumption and investment at home, or sold abroad. This good is an imperfect substitute for the foreign final good, and its production requires the use of an imported intermediate input.

Domestic private agents hold four assets: money, domestic debt issued by the consolidated public sector (i.e., the government plus the central bank), foreign assets, and equity claims on the domestic capital stock. Money allows for inflationary finance of budget deficits. There are no restrictions to capital mobility and in the absence of risk and uncertainty, all non-monetary assets are assumed to be perfect substitutes. Hence anticipated asset returns satisfy the corresponding uncovered parity conditions. Foreigners hold domestic equity but not domestic public debt. Finally, the public sector also holds foreign assets.[2]

Both goods and asset markets clear continuously. Equality between demand and supply of the domestic goods determines the real exchange rate. Under a flexible nominal exchange rate regime, money market equilibrium with an exogenously set money supply determines the nominal exchange rate. In contrast, the labor market may not clear instantaneously due to real and/or nominal wage rigidity. Wages are indexed to current and past consumer price inflation, and react slowly to deviations from full employment.

The dynamics of the model arise from two basic sources: the accumulation of assets/liabilities, dictated by stock-flow consistency of the sectoral budget constraints, and the forward-looking behavior of private agents. Expectations are formed rationally, which in this context of certainty amounts to perfect foresight. Thus, anticipated and realized values of the variables can differ only at the time of unexpected shocks or due to the arrival of new information about the future paths of exogenous variables.

Behavioral rules combine explicitly two benchmark specifications: the neoclassical case of unconstrained, intertemporally-optimizing firms and consumers, along with labor market clearing, and the Keynesian case of liquidity-constrained firms and households, along with wage inflexibility.[3] Following the standard theory of investment under convex adjustment costs (Lucas, 1967, Treadway, 1969), unconstrained firms maximize their market value and link their investment decisions to Tobin's

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[2] Foreign assets held by the domestic private and public sectors are net assets (equal to gross foreign reserves plus other gross foreign assets less gross foreign liabilities) and therefore can have either sign.

[3] Export demand and wage setting are the only behavioral equations in the model that do not follow (explicitly or implicitly) from first principles.

q (Tobin, 1969), i.e., the present value of the additional profits associated with the marginal unit of capital relative to its installation cost (Hayashi, 1982). Unconstrained consumers gear consumption to their permanent income, as derived from intertemporal utility maximization along Ramsey-type behavior (Ramsey, 1928). In contrast, constrained firms (consumers) gear their investment (consumption) expenditure to their current profits (disposable income).

Technology and preferences are kept as simple as possible -- mostly by assuming unit elasticities of substitution. Two-stage budgeting in consumption and investment allows separation between the determination of expenditure and its allocation to domestic and foreign goods (thus avoiding the use of ad-hoc import functions). Harrod-neutral technical progress ensures the existence of steady-state growth, at a level given by the sum of the rates of technical progress and population growth, both of which are exogenous.

The model's detailed structure is introduced next, starting with sector flow budget constraints and market equilibrium conditions. Behavioral equations for firms, consumers, the public sector, and the external sector follow. Variable notation and definitions are summarized in Table 1; all prices are defined relative to the price of the domestic good or to the foreign price level. All stock and flow variables other than prices and interest rates are scaled to the labor force in efficiency units.[4] The model is written in continuous time. Dots over variables denote right-hand time derivatives.

2.1 Budget Constraints

There are three basic agents in the model: the consolidated public sector, the domestic private sector, and the external sector. The first lumps the non-financial and financial (central bank) public sector together, the second aggregates private firms and consumers, and the third adds foreign investors, creditors, and trade partners. While some further disaggregation between firms and consumers is implicit below, we do not need it at this stage.

Walras' law makes one of the three sectoral budget constraints redundant when combined with goods and assets markets clearing. Hence we present the three budget constraints below only for expositional convenience. They are written equating above-the-line current account surpluses with below-the-line increases in net real asset holdings per effective labor force unit. Therefore above-the-line interest flows are adjusted for the changes in real asset holdings per effective labor unit due to growth in effective labor (g) and inflation.

[4] Labor force in efficiency units is equal to the actual labor force augmented by Harrod-neutral technical progress (see Table 1).

TABLE 1: NOTATION AND DEFINITION OF VARIABLES

1. Labor and Employment

L	Absolute employment
$LF = LF_0 \exp(pg\ t)$	Absolute labor force
LF_0	Base-period absolute labor force
$N = L \exp(tg\ t)$	Absolute employment in efficiency units
$NF = LF \exp(tg\ t) = LF_0 \exp(g\ t)$	Absolute labor force in efficiency units
pg	Population growth rate
tg	Harrod-neutral technical progress rate
$g = pg + tg$	Growth rate of absolute labor force in efficiency units
t	Time index
$l = L/LF = N/NF$	Employment (relative to labor force)
ld	Labor demand (relative to labor force)

2. General Notation

All stock and flow variables other than interest rates are defined in real terms and in efficiency labor force units. Current-price domestic (external) income and transfer flows and prices are deflated by the price of the domestic good (external price deflator). All stock and flow variables other than prices and interest rates are defined in terms of units of effective labor force. Domestic (external) relative prices are measured in real domestic (external) currency units. A dot over a variable denotes its right-hand time derivative.

3. Income, Transfer and Capital Flows

Domestic:	
d	Dividends paid
op	Operational profits
td	Taxes
yd	Private disposable income
prem	Profit remittances abroad
External:	
ftrg	Foreign transfers to the public sector
ftrp	Foreign transfers to the private sector
yf	Foreign income
dfi	Direct foreign investment

4. Stocks

Domestic:	
a	Non-human wealth of the private sector
bg	Domestic debt of the public sector
fe	Stock of domestic equity (shares in domestic firms) held by foreigners
hb	Domestic base money
hu	Human wealth of the private sector
k	Physical capital
pvig	Present value of government investment subsidy
pvihb	Present value of cost of holding money
External:	
fbg	Foreign assets held by the public sector
fbp	Foreign assets held by the private sector

TABLE 1 (Cont.)

5. Goods Flows

y	Gross output of final goods
cp	Private aggregate consumption
cmp	Private imported-goods consumption
cnp	Private national-goods consumption
cng	Public national-goods consumption
inv	Gross domestic investment
in	Private national-goods investment
im	Private imported-goods investment
ig	Public investment subsidy
iac	Investment adjustment costs
x	Exports
mr	Intermediate imports

6. Various Rates

Domestic (External) Rates:

i (if)	Nominal interest rate on public debt (foreign assets/liabilities)
r (rf)	Real interest rate on public debt (foreign assets/liabilities)
i-r (if-rf)	Anticipated domestic (External) inflation rate
nmg	Rate of growth of the nominal money stock

7. Goods Prices

Domestic (all relative to the price of the domestic final good):

pc	Private aggregate consumption deflator
pi	Aggregate investment deflator

External (all relative to the price of the foreign final good):

pcmp	Private imported-goods consumption deflator
pim	Imported-goods investment deflator
pmr	Intermediate imports deflator
px	Deflator of export-competing goods

8. Other Prices

Domestic Prices:

q	Real equity price (Tobin's Q) in units of domestic output
v	Real wage per effective labor unit
W	Nominal wage per labor unit
PC	Nominal private consumption deflator

Real Exchange Rate:

$e = (E P^*)/P$	Real exchange rate
E	Nominal exchange rate
P	Nominal price of the domestic good
P^*	Nominal external deflator (foreign price level)

Public revenue includes conventional taxes, unrequited foreign transfers, growth-adjusted interest earnings from public assets held abroad, and the return on base money. The latter equals the sum of the inflation tax and the monetary revenue due to the growth of efficiency labor units. Public expenditure includes public consumption, which is assumed to fall entirely on domestic goods, an investment subsidy paid to domestic firms[5], and interest paid on the outstanding stock of domestic public debt. Revenues include direct taxes, interest on net foreign assets of the public sector, and the inflation tax. The resulting adjusted operational surplus of the consolidated public sector finances acquisition of foreign assets and retirement of base money and domestic debt:

$$\text{(1)}\quad \begin{aligned} &[td + e\ ftrg - cng - pi\ ig] - (r-g)\,bg + (g+\dot{P}/P)\,hb \\ &+ e(rf - g)\,fbg = e\,\dot{fbg} - \dot{bg} - \dot{hb} \end{aligned}$$

The external sector budget constraint -- the balance of payments identity -- reflects trade in goods and non-factor services, unrequited transfer payments to both the public and private sectors, loans from both domestic sectors, and foreign investment flows toward the private sector as well as profit remittances from the latter. Therefore, the external adjusted current account surplus and its financing, for convenience written in constant-price foreign currency units, is the following:

$$\text{(2)}\quad \begin{aligned} &\left[\frac{x}{e} - pcmp\ cmp - pim\ im - pmr\ mr + ftrg + ftrp\right] \\ &+ (rf-g)\,[fbp + fbg] - \frac{prem}{e} = (\dot{fbp} + \dot{fbg}) - dfi \end{aligned}$$

The private sector budget constraint reflects the assumption that private firms do all production and investment decisions, own the economy's entire capital stock, and benefit from a public investment subsidy. Firm ownership is split between domestic consumers and foreigners. The consolidated domestic private sector (firms and consumers) budget constraint is given by:

$$\text{(3)}\quad \begin{aligned} &[y - pi\ inv - pi\ iac - e\ pmr\ mr + e\ ftrp - td + pi\ ig - pc\ cp] \\ &- (g+\dot{P}/P)\,hb + (r-g)bg - prem + (rf-g)\,e\,fbp \\ &= \dot{hb} + \dot{bg} - e\,dfi + e\,\dot{fbp} \end{aligned}$$

[5] Public sector ownership of the capital stock could be mimicked by introducing a tax on profits proportional to the cumulative volume of public investment. For simplicity, we do not pursue this option here. Also, we are implicitly assuming that public investment is a perfect substitute for private investment.

2.2 Market Equilibrium Conditions

Equilibrium conditions are specified for goods, asset, and labor markets. Continuous market clearing at equilibrium prices and asset returns characterizes goods and asset markets, while sluggish wage adjustment is observed, under the general case, in the labor market.

Goods Markets

The single good produced domestically can be used for consumption and investment at home, or sold abroad (thus there is no distinction between production for domestic and export markets). It is an imperfect substitute for the foreign final good. However, the economy is small in its import markets by assumption. Equilibrium in the market for domestic goods can be expressed:[6]

$$y = cnp + cng + in + pi\ iac + x \tag{4}$$

Under continuous market clearing, this is an implicit equation for the real exchange rate.

Asset Markets

Asset market equilibrium conditions are specified for base money, domestic bonds, and equity claims on the fixed capital stock. They reflect three features: perfect capital mobility, external interest rate determination in international markets (the small country assumption for financial markets), and absence of uncertainty (no risk premia). Imperfect substitutability between base money and other assets is reflected by a conventional transactions-based demand for base money. In turn, domestic and foreign bonds, as well as equity, are assumed perfect substitutes; hence their anticipated rates of return must be equalized at each point in time.

Base money market equilibrium assumes a conventional Cagan-type money demand (Cagan, 1956):[7]

$$hb = \phi_1\, y^{\phi_2} \exp(\phi_3 i) \tag{5}$$

where $\phi_1, \phi_2 \geq 0, \phi_3 \leq 0$.

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[6] Notice that gross output y differs from conventional national-accounts value added or GDP for two reasons: y is defined as gross of the value of intermediate imports (e pmr mr) and gross of the value of investment adjustment costs (pi iac).

[7] Money demand could be explicitly derived from first principles by bringing money into the utility function (Sidrausky, 1967) or the production function (Fischer, 1974), or by imposing a cash-in-advance transactions technology (Clower, 1967). Easterly, Mauro and Schmidt-Hebbel (1992) present a generalized cash-in-advance transactions technology (with iso-elastic substitution of money and bonds) giving rise to variable elasticity of money demand with respect to inflation, generalizing the iso-elastic Cagan form. In turn, equation (5) in the text can be rigorously derived from a technology combining money and productive inputs to produce final goods; constant returns to scale would imply $\phi_2 = 1$.

Arbitrage between domestic and foreign bonds leads to the uncovered interest parity condition:

(6) $$r = rf + \frac{\dot{e}}{e}$$

Similarly, arbitrage between equity and domestic public bonds is reflected by the following market equilibrium condition for equity prices (Tobin's q):

(7) $$\dot{q} = r\,q - \frac{d}{k}$$

Finally, the nominal interest rate is defined by the standard Fisher equation:

(8) $$i = r + \frac{\dot{P}}{P}$$

Labor Market

In the general case, wage rigidity (nominal and/or real) prevents the labor market from clearing instantaneously. We follow the conventional assumption that employment is determined by labor demand:

(9) $$l = ld$$

The labor market follows a wage-setting rule, which states that nominal wages are indexed to current and lagged consumer price inflation (with weights Θ and $1\text{-}\Theta$, respectively) and also respond to current labor market conditions (with an elasticity ω with regard to employment). Anticipating the simulations, the nominal wage equation is written in discrete-time form:

$$W = \exp(tg)\, l^{\omega} \left(\frac{PC}{PC_{-1}}\right)^{\theta} \left(\frac{PC_{-1}}{PC_{-2}}\right)^{1-\theta} W_{-1}$$

where $\omega \geq 0$, $0 \leq \Theta \leq 1$.

Using the relation between the nominal wage and the real (product) wage per effective labor unit:

$$\frac{W}{P} = \exp(tg\,t)\; v$$

we obtain, after some manipulations, the following real wage equation:

$$(10) \qquad v = l^{\omega}\left(\frac{pc}{pc_{-1}}\right)^{\theta}\left(\frac{pc_{-1}}{pc_{-2}}\right)^{1-\theta}\left[\frac{P_{-1}/P_{-2}}{P/P_{-1}}\right]^{1-\theta} v_{-1}$$

This wage rule encompasses several interesting cases. First, when ω tends to infinity, it collapses into the neoclassical full-employment condition ($l = 1$). Second, for finite ω and $\theta = 1$, it represents the case of real wage resistance. In turn, with finite ω and $\theta < 1$, wages display nominal inertia. Finally, ex-post inflation can be defined from the relation between real and nominal balances per effective labor unit:[8]

$$\frac{P}{P_{-1}} = \frac{hb_{-1}}{hb}\,\frac{(1+nmg_{-1})}{(1+g)}$$

2.3 Firms

Technology is summarized by a Cobb-Douglas production function for gross output with Harrod-neutral technical progress, and quadratic adjustment costs for investment. The investment technology combines domestic and imported final goods according to a Cobb-Douglas specification, which allows for two-stage budgeting.[9]

There are two groups of firms. The first group is not subject to liquidity constraints and determines its investment according to the maximization of market value -- i.e., the present value of future dividends -- subject to convex adjustment costs. Investment is financed by equity sold to domestic and foreign agents and through the public investment subsidy. However, because the latter is distributed to firms in lump-sum fashion, it has no effect whatsoever on investment by unconstrained firms; for them, the subsidy is simply a source of increased dividends.

The second group of firms is restricted in its access to financial markets and gears its current investment to current profits inclusive of the public investment subsidy. Thus, for these constrained firms changes in the subsidy will affect fixed investment levels.

The production technology for gross output is described by a Cobb-Douglas production function, which allows for substitution between value added (capital and labor) and intermediate imports:

$$(11) \qquad y = \alpha_0\, ld^{\alpha_1}\, k^{\alpha_2}\, mr^{(1-\alpha_1-\alpha_2)}$$

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[8] Notice that, from (8), i-r is a measure of anticipated one-period ahead inflation. Because of the rational expectations assumption, it will equal actual (one-period ahead) inflation except at times of 'news' about the current and/or future paths of the exogenous variables.

[9] Wildasin (1984) provides exact conditions under which the investment technology gives rise to a two-stage investment decision. See also Hayashi and Inoue (1991) for a recent generalization with empirical applications.

where $\alpha_0 \geq 0,\ 0 \leq \alpha_1,\ \alpha_2 \leq 1.$

Investment adjustment costs are defined by:

$$(12) \qquad iac = \mu\left[\frac{(inv - (g+\delta)k)^2}{k}\right]$$

where $\mu > 0$. This specification has the useful property that adjustment costs vanish in steady-state equilibrium -- i.e., when gross investment per unit of effective labor is just sufficient to maintain the capital/effective labor ratio. The evolution of the latter is described by:

$$(13) \qquad \dot{k} = inv - (g+\delta)k$$

Market value maximization for unconstrained firms, as well as current profit maximization for constrained firms, yields the standard marginal productivity conditions for variable inputs (labor and imported materials):[10]

$$(14) \qquad ld = \alpha_1\, v^{-1}\, y$$

$$(15) \qquad mr = (1 - \alpha_1 - \alpha_2)\,(e\ pmr)^{-1}\, y$$

Investment demand is, as described above, a combination of the market-value maximizing investment rule of unconstrained firms and the profit-constrained investment of restricted firms:

$$(16) \qquad inv = \beta_1\left[\frac{k}{2\mu}\left[\frac{q}{pi} - \frac{pvig}{pi\,k} - 1\right] + (g+\delta)\,k\right] + (1-\beta_1)\left[\beta_2\,\frac{op}{pi} + ig\right]$$

where β_1 is the share of non-constrained firms and β_2 is the marginal propensity of liquidity-constrained firms to invest out of operational profits; $0 \leq \beta_1, \beta_2 \leq 1$.

Unconstrained investment (the content of the first large right-hand side parenthesis) is derived from maximization of the value of the firm. This component of aggregate investment demand is geared to Tobin's marginal q -- i.e., average q minus the present value of the public investment subsidy per unit of capital[11]. This reflects the fact that optimal investment is determined by the addition to future dividends of the marginal unit of capital, which excludes the subsidy due to its lump-sum nature. By

[10] The derivation of these conditions, as well as of the unconstrained component of investment in equation (16) below, follows the standard maximization of the value of the firm, subject to equations (11) - (13), not presented here for brevity.

[11] The general reasons that cause marginal and average q to diverge are spelled out in Hayashi (1982).

contrast, the average value of existing capital (i.e., the present value of the dividends associated with an installed unit of capital) must include the subsidy. In turn, investment by constrained firms (the last term in the right-hand of (16)) rises one-for-one with the investment subsidy.

The present value of the public investment subsidy is implicitly defined by the dynamic equation:

$$(17) \qquad \dot{pvig} = (r-g)\ pvig - pi\ ig$$

Aggregate operational profits -- which determine capital formation by liquidity-constrained firms -- are defined as:

$$(18) \qquad op = y - v\ l - e\ pmr\ mr$$

and dividends are the sum of operational profits, net of investment expenditure, the investment subsidy and the proceeds of new issues of equity:

$$(19) \qquad d = op - pi\ inv - pi\ iac + pi\ ig + q(\dot{k} + gk)$$

After determining aggregate investment according to equation (16), the second-stage investment decision involves allocating investment expenditure between domestic goods and imports, according to a Cobb-Douglas aggregation which renders constant expenditure shares:

$$(20) \qquad in = \gamma\ pi\ inv$$

$$(21) \qquad im = (1-\gamma) \left[\frac{pi}{e\ pim}\right] inv$$

where γ is the share of national-goods investment in aggregate investment expenditure, satisfying $0 \leq \gamma \leq 1$. Therefore the aggregate investment deflator is a Cobb-Douglas average of national-goods investment prices and imported investment-goods prices:

$$(22) \qquad pi = (e\ pim)^{(1-\gamma)}$$

2.4 Consumers

Consumer preferences also allow two-stage budgeting distinguishing between intertemporal aggregate consumption decisions and intratemporal consumption composition choices. Intertemporal preferences reflect unit intertemporal elasticity of substitution (i.e., logarithmic intertemporal utility); intratemporal preferences also display unit elasticity of substitution between domestic and imported goods.

Private sector non-human wealth includes four assets: base money, domestic public bonds, foreign assets, and equity claims on the domestic capital stock.

$$\text{(23)} \qquad a = hb + bg + e\ fbp + q(k-fe) - pvihb$$

where the present value of money holding costs pvihb has to be subtracted from financial wealth; it is implicitly defined by the dynamic equation:

$$\text{(24)} \qquad \dot{pvihb} = (r-g)\ pvihb - i\ hb$$

Human wealth is the present value of future labor income, net of taxes, and inclusive of current external transfers.[12] Under the assumption that individuals can freely borrow against their future labor income at the going real interest rate, the path of human wealth is characterized by:

$$\text{(25)} \qquad \dot{hu} = (r-g)\,hu + [td - vl - e\ ftrp]$$

Consumption of non-liquidity constrained consumers is derived from standard maximization of intertemporal utility over an infinite horizon, subject to the intertemporal budget constraint equivalent of the private sector flow constraint in equation (3) -- which is exactly consistent with wealth definitions in equations (23) - (25). Solving the maximization problem yields the standard result that private consumption of unconstrained households is equal to the subjective discount rate (net of effective labor growth) times total (human and non-human) wealth.[13]

Unconstrained consumers are of course Ricardian, as they internalize the government's intertemporal budget constraint by anticipating the entire stream of current and future tax payments. Because liquidity-unconstrained consumers face the same discount rate as the government[14], they are indifferent between tax, debt, or money financing. Therefore government debt -- although included in equation (23) -- ultimately "is not wealth" (Barro, 1974).

Total private consumption demand is an aggregate of consumption by unconstrained and constrained consumers, with the latter consuming their current net labor income:[15]

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[12] For expositional convenience, all taxes and transfers have been lumped together in the human capital flow equation. Since both accrue in lump-sum fashion, this is of no consequence for the model's properties.

[13] As before, the analytical derivations are standard and can be omitted.

[14] The assumption of equal discount rates is crucial for Ricardian equivalence to hold. Higher private sector discount rates, whether due to finite lifetimes (reflected by a given probability of death, as in Blanchard, 1985) or to a risk premium on consumers' debt relative to the borrowing cost of the government (e.g., McKibbin and Sachs, 1989) would cause Ricardian equivalence to break down.

[15] For discussion and empirical analyses of the implications of liquidity constraints for consumer behavior -- as well as for Ricardian equivalence -- see, for example, Hayashi (1985), Hubbard and Judd (1986), Bernheim (1987), Leiderman and Blejer (1988), and Seater (1993).

(26) $$cp = \lambda_1 \left[(\lambda_2 - g) \frac{a + hu}{pc} \right] + (1 - \lambda_1) \left[\frac{yd}{pc} + (\lambda_2 - g) \frac{a}{pc} \right]$$

where $0 \leq \lambda_1 \leq 1$ is the share of unconstrained consumers, and λ_2 is the subjective discount rate. Disposable income is defined by:

(27) $$yd = v\,l + e\;ftrp - td$$

After determining aggregate private consumption levels according to equation (25), the second-stage private consumption decision allocates it to domestic goods and imports, according to Cobb-Douglas intratemporal preferences:

(28) $$cnp = \eta\;pc\;cp$$

(29) $$cmp = (1 - \eta) \left[\frac{pc}{e\;pcmp} \right] cp$$

where $0 \leq \eta \leq 1$ is the share of national-goods in aggregate private consumption expenditure. Therefore the aggregate private consumption deflator is a Cobb-Douglas index of national-goods prices and imported consumption goods prices:

(30) $$pc = (e\;pcmp)^{(1-\eta)}$$

2.5 Government

The public sector could either determine policy exogenously or derive it from optimization of some objective function; for realism and simplicity, we choose the first option. Thus public consumption and investment expenditures are exogenously given. To finance its activity, the public sector can choose among taxes, money, domestic debt or external borrowing (or any combination of them).

The accumulation of per capita real balances can be characterized as:

(31) $$\dot{hb} = \left[nmg - (\dot{P}/P) - g \right] hb$$

where it is worth noting that the rate of money growth nmg will be endogenous under money finance of the deficit and exogenous otherwise.

2.6 Foreigners

The demand by foreigners for the domestically produced good is given by a conventional export function, which embodies imperfect substitution between the national good and the foreign final good and a normal relation to foreign income:

$$(32) \qquad x = \rho_1 (e\ px)^{\rho_2}\ yf^{\rho_3}$$

where $\rho_1, \rho_2, \rho_3 \geq 0$.

Finally, the path of foreigners' equity holdings remains to be described. At every instant, foreign investors use dfi units of foreign currency (in real per capita terms) to purchase domestic shares, whose price in terms of domestic output is q. Hence their per-capita holdings of equity evolve according to the equation:

$$(33) \qquad \dot{fe} = \frac{e\ dfi}{q} - g\ fe$$

In turn, profit repatriation equals the total volume of dividends earned by foreign investors, which is given by the product of the share of foreign-held equity and total dividends:

$$(34) \qquad prem = \frac{fe}{k}\ d$$

3. STEADY STATE AND STABILITY

3.1 The Steady State

The long run equilibrium of the model is characterized by constant asset stocks in real per capita terms, constant asset prices (i.e., Tobin's q and the real exchange rate), and constant real wages with full employment. Thus, the government's budget must be balanced, and the current account deficit must equal the exogenously given flow of foreign investment, which in turn is just sufficient to keep foreign equity holdings (in real per capita terms) unchanged.

Since the per capita real money stock is constant, long run inflation equals the rate of expansion of per capita nominal balances nmg-g. In turn, with a constant real exchange rate, domestic and foreign real interest rates are equalized by uncovered interest parity, and nominal exchange depreciation is determined by the difference between domestic and (exogenously given) foreign inflation. Hence, across steady states changes in the rate of money growth are fully reflected in the inflation rate (and thus in the nominal interest rate) and in the rate of nominal depreciation.

By combining the model's equations, the steady-state equilibrium can be reduced to two independent equations in the real exchange rate, real wealth, and the real interest rate: a goods market equilibrium condition, and a zero private wealth accumulation condition (in real per capita terms).[16] Together they imply a constant stock of per capita net foreign assets. Real wealth accumulation can cease only when per capita consumption equals the per capita return on wealth. But the latter is just (rf-g) times the wealth stock (because of the assumption of perfect asset substitutability), while in the steady-state the former equals (λ_2-g) times the wealth stock (from (25)-(27)).[17] Hence, this implies the well-known result that the rate of time preference λ_2 must equal the exogenously given foreign real interest rate:

$$\lambda_2 = rf \tag{35}$$

Since (35) provides no information on the steady state wealth stock, we would be left only with the goods market equilibrium condition to determine both wealth and the real exchange rate--an obviously impossible task. This means that their steady-state values (and hence also those of all variables that depend on them) depend not only on the long-run values of the exogenous variables, but also on the initial conditions and on the particular adjustment path followed by the economy -- and therefore on parameters governing the speed of adjustment such as the degree of real wage rigidity or the magnitude of adjustment costs associated with investment. In other words, the model exhibits hysteresis. As noted by Giavazzi and Wyplosz (1984), this follows from the assumption of forward-looking consumption behavior derived from intertemporal optimization by infinitely-lived households with a constant rate of time preference and facing perfect capital markets.

Nevertheless, certain important features of the steady state can easily be determined.[18] On the production and investment side, long run equilibrium is characterized by full employment and a constant capital stock in per capita terms. From (13), gross investment is just inv = $(g+\delta)k$, and adjustment costs are identically zero (from (12)). In turn, from (7), (17), (18) and (19), Tobin's q in steady state is given by:

$$q = \frac{F_k - pi\ (g+\delta)}{(rf-g)} + pvig/k \tag{36}$$

where F_k is the marginal productivity of capital. If no firms are liquidity constrained (that is, $\beta_t = 1$ in (16)), then (16) further guarantees that marginal q equals the price of capital goods or, equivalently, that average q equals the price of capital plus the unit investment subsidy (i.e. q = pi + pvig/k). Thus, from the above equation the marginal product of capital equals its user cost:

$$F_k = pi\ (rf+\delta) \tag{37}$$

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[16] See Serven (1994) for an analysis of the steady-state and dynamic properties of the non-monetary neoclassical version of our model.

[17] This is strictly correct only in the absence of liquidity constraints (λ_1 = 1). However, when $\lambda_1 < 1$, wealth accumulation would still equal (r - λ_2) times the wealth stock of unconstrained consumers (a + λ_1 hu).

[18] Giavazzi and Wyplosz (1985) provide a method to solve analytically certain linear models with hysteresis. They show that the long-run equilibrium depends on initial conditions and on the speed of adjustment of the system. Since our model is nonlinear, however, a comparable solution technique is not available.

Notice, however, that pi is an increasing function of the real exchange rate because of the import content of capital goods. In turn, for a given capital stock F_k is a decreasing function of the real exchange rate, due to the use of imported materials in production. Hence, (37) defines an inverse relationship between the steady-state capital stock and the real exchange rate: across steady states, a real depreciation must reduce the capital stock, and (from (11) and (14)) also output and the real wage. It also follows that the long-run values of these variables depend, like the real exchange rate, on initial conditions and on the adjustment path of the economy.[19]

What if some firms are liquidity constrained (i.e., $\beta_1 < 1$) ? The negative long-run relationship between the capital stock and the real exchange rate is unaltered; however, in the steady state q does not equal the subsidy-inclusive price of capital goods, nor does F_k equal the user cost of capital. Provided the marginal propensity to invest of constrained firms (β_2 in (15)) is not too large,[20] the marginal product of capital must exceed the user cost, and Tobin's q must exceed the price of capital goods plus the investment subsidy. Formally:

$$(38) \qquad F_k = pi\ [(rf+\delta) + f]$$

where $f > 0$ is a term that depends positively on the adjustment cost coefficient μ and the rate of depreciation of capital, and negatively on β_1, β_2 and the investment subsidy.[21] Tobin's q under liquidity constraints becomes:

$$(39) \qquad q = \frac{pi\ [(rf+\delta) + f]}{(rf+\delta)} + pvig/k$$

The intuition behind these results is simple: with binding liquidity constraints, firms cannot invest as much as they would want and therefore cannot close the gap between the shadow value of one additional unit of capital and its cost. This implies that, for a given long-run real exchange rate, liquidity constraints will cause the economy to achieve a lower capital stock and output, and a lower real wage as well, than in the fully unconstrained case.

Using (37) or (38), the steady-state goods market equilibrium condition (4) can be rewritten as:

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[19] See Serven (1994) for further elaboration. This is in contrast to similar dynamic models (e.g., Sachs (1983), Giavazzi et al. (1982)), where capital goods have no import content and thus the steady-state marginal product of capital (as well as the capital stock and real output) depends only on the relative price of materials in terms of domestic goods (e pm in our notation). Here the import content of capital goods creates a negative relationship between the real exchange rate and F_k, even for a given real cost of imported inputs. Gavin (1991) and Serven (1991) have shown that this has important consequences for the effects of macroeconomic policies on investment.

[20] The exact condition is $\beta_2 < (g+\delta)/(rf+\delta) - ig/(\alpha_2 y)$.

[21] The exact expression for f is $f = \dfrac{\beta_1(rf+\delta) + (1-\beta_1)\ 2\mu\ (rf-g)(g+\delta)}{\beta_1 + (1-\beta_1)\ 2\mu\ (rf-g)(\beta_2 + \frac{z}{\alpha_2})} - (rf+\delta)$, where $z = \dfrac{ig}{y}$ is the public investment/gross output ratio.

(40) $$y(e,...) = \eta\ (rf-g)(a+hu) + cg + \gamma\ pi\ (g+\delta)\ k(e,...) + x(e,...)$$

which defines an inverse relationship between the long-run real exchange rate and real wealth: an increase in the real exchange rate (a real depreciation) generates excess demand for domestic goods and requires a fall in private wealth and consumption to restore market equilibrium.[22] As noted before, the particular levels of real wealth and the real exchange rate that will obtain in the long run depend on the initial conditions and on the dynamic path followed by the economy.

Aside from real wealth, the other key element in the determination of the long-run real exchange rate is the distribution of demand between the public and private sectors. Since public consumption is assumed to have no import content, an increase in cng creates excess demand for domestic goods and leads to a real appreciation. As argued before, this would cause the capital stock and output to rise as well.

An important implication of the model's hysteresis property is that transitory disturbances have long-run effects. For the case of fiscal policy, this has been recently highlighted by Turnovsky and Sen (1991).[23] In our framework this also means that even transitory monetary disturbances can have permanent real effects: if some consumers are liquidity constrained (or myopic), a transitory increase in inflationary taxation matched by a reduction in direct taxes will raise disposable income and consumption, leading to reduced wealth accumulation and eventually causing a fall in long-run wealth and a permanent real depreciation.[24]

3.2 Dynamics, Stability and Model Solution

The precise dynamics of the model depend on the way the public deficit is financed. Under tax or money finance, the model is driven by ten dynamic equations. Four of them describe the time paths of predetermined variables: the capital stock, private foreign assets, foreign holdings of equity, and the real wage. At each moment in time, these variables are given by current and past values of endogenous and exogenous variables. Further, the four predetermined variables have to satisfy well-defined initial conditions. Under debt (domestic or foreign) finance, a fifth dynamic equation describes the time path of the relevant debt stock.

The remaining six dynamic equations describe the time paths of 'jumping' variables: Tobin's q, the real exchange rate, real money balances, human wealth, the present value of the investment subsidy,

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[22] This is guaranteed by our assumption of constant expenditure shares of domestic goods and imports in private consumption and investment. With more general specifications allowing lower substitutability between domestic and foreign goods, a positive association between real wealth and the real exchange rate in steady state (i.e., a "contractionary devaluation" of the type analyzed by Krugman and Taylor (1978)) could not in principle be ruled out.

[23] Turnovsky and Sen (1991) use a non-monetary model with intertemporally optimizing consumers to show that transitory fiscal disturbances have long-run effects. Their result depends critically on the endogeneity of labor supply in their framework, which makes long-run employment endogenous. In our case, the dependence of the long-run capital stock on the real exchange rate ensures that transitory fiscal shocks have permanent effects despite the constancy of full employment across steady states.

[24] Without liquidity constraints, a monetary acceleration (an increase in nmg) holding constant public consumption would just amount to a change in the composition of taxation between the inflation tax and (present or future) direct taxes (or transfers), without any effect on wealth, consumption, or any other real variable.

and the present value of the cost of holding money. They are not predetermined by the past and can react freely to 'news' about current and future values of exogenous variables; their equilibrium values at any point in time depend on the entire future anticipated path of the forcing variables. For the complete dynamic system not to explode, these jumping variables have to satisfy certain terminal (transversality) conditions. Solving the model basically amounts to finding initial values for the non-predetermined variables such that, following a shock, the model will converge to a new stationary equilibrium.

The necessary and sufficient conditions for the existence and uniqueness of such initial values in linear models of this type have been investigated in the literature and will not be discussed here.[25] However, this is not the case for large nonlinear models such as this one.[26] While a formal proof of stability cannot be provided, numerically the model was always found to converge to the new long-run equilibrium under reasonable parameter values.

The requirement that the predetermined variables satisfy initial conditions, while the jumping variables must satisfy terminal conditions, poses a two-point boundary-value problem, for whose numerical solution several different techniques exist. One leading example is the "multiple shooting" method proposed by Lipton et al. (1982), which solves the model over a fixed time horizon starting from arbitrary guesses for the initial and future values of the jumping variables. The second is the "extended path" algorithm of Fair and Taylor (1983), which first solves the model also over a fixed time horizon, but starting from arbitrary guesses for the expected values of the jumpers, which are updated until they become sufficiently close to the actual values obtained from the model's equations, and then gradually extends the horizon until the solution path is unaffected by the addition of more time periods.

For the simulations below, we combine both techniques. First, we solve the model over an arbitrarily chosen time horizon using multiple shooting. To prevent the solution from being distorted by the choice of too short a time horizon (which would force the model to reach the terminal conditions too early), we then extend the horizon and recompute the solution path until the resulting changes in the solution trajectory of the endogenous variables fall below a certain tolerance,[27] at which time the process stops. In practice, the length of the simulation horizon required for this procedure to converge is strongly affected by two parameters governing the speed of adjustment of the system: the elasticity of real wages to employment (i.e., the slope of the augmented Phillips curve), and the magnitude of adjustment costs associated with investment. Finally, the model is made discrete for the numerical simulations, so for any variable x, $\dot{x} = x_{+1} - x$.

4. SIMULATION RESULTS

This section discusses the dynamic response to external shocks, by presenting simulation results for the model introduced above. In a companion paper (Schmidt-Hebbel and Serven, 1993) we have

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[25] See Blanchard and Kahn (1980) and Buiter (1984).

[26] In principle, we could linearize the system around a steady state to determine analytically the conditions under which the transition matrix possesses the saddle-point property. For a tenth-order system, however, this would be an intractable task.

[27] We used a very strict convergence criterion, requiring that the maximum relative change between solutions in any variable at any time period not exceed one-thousandth of one percent. This typically required a horizon between sixty and eighty periods for convergence.

explored the model's response to a favorable foreign transfer shock (an external grant) and a favorable terms-of-trade shock (a decline in the price of the intermediate import used in production, say oil). We simulate the dynamic adjustment to fiscal and monetary policy shocks. The first-round magnitude of both shocks is common, equivalent to a 4% gain of initial steady-state output. We start by introducing the values of model parameters and exogenous variables and presenting the values of the endogenous variables at the initial steady-state equilibrium. Then we discuss the simulation results.

4.1 Model Parameterization and Initial Steady-State Solution

Within the general structure spelled out above, two economies will be considered: (i) a neoclassical (NC) benchmark, and (ii) a Keynesian benchmark combining liquidity constraints and unemployment. Table 2 summarizes the common and distinct parameter values for these three economies. Under the neoclassical benchmark, liquidity constraints on consumption and investment are ruled out ($\beta_1 = \lambda_1 = 1.0$). For the Keynesian case, the latter coefficients are reduced to 0.5. For the full-employment cases, the elasticity of real wage changes with respect to current employment is set at a very high level ($\omega = 1{,}000$) and indexation to lagged consumer-price inflation is ruled out ($\Theta = 1.0$). By contrast, wage-setting behavior in the Keynesian benchmark gives rise to unemployment, as a result of a low employment elasticity ($\omega = 0.25$) and an important role of lagged inflation ($\Theta = 0.5$). The latter feature reflects nominal stickiness of wages.

Numerical values for other coefficients in the structural equations were borrowed from empirical estimates (Serven and Solimano, 1991, Elbadawi and Schmidt-Hebbel, 1991) and preceding simulation models (McKibbin and Sachs, 1989, Giavazzi and Wyplosz, 1984) for various countries, complemented by estimates deemed to be representative for open economies. Table 2 also reports these parameter values shared by the three economies. Base money demand exhibits unit income elasticity. The interest semi-elasticity is 0.5, implying a seignorage-maximizing inflation rate of 200%. The share of labor, capital and intermediate imports in production (gross of imported materials) is 0.6, 0.3, and 0.1, respectively. The quadratic adjustment coefficient of investment is 2.5 and the rate of capital depreciation is 0.04. The import component of aggregate investment is relatively large (0.4), exceeding that of private consumption (0.1). The rate of discount of consumers is set at 0.06, which, according to equation (35), is also equal to the foreign real interest rate. Export demand exhibits a unitary foreign-income elasticity. The price elasticity of foreign demand for exports is 1.5.

Before discussing the values of exogenous variables, a remaining question on model closure has to be addressed: one residual endogenous variable for each of the two independent budget constraints remains to be chosen. For the simulations discussed below, the adjusting variable for the public sector will be either taxes (td), or domestic debt (bg), or money growth (nmg); and for the private sector the residual budgetary variable is foreign asset holdings (fbp).[28]

The numerical values for exogenous variables are also based on both representative country magnitudes (as ratios to output) and previous models. Table 3 summarizes the exogenous variables for the initial steady state, common to the three economies. While the simulations show the response to changes in one exogenous variable (public consumption), all other exogenous variables are maintained at the levels summarized in table 3. Because in the initial steady-state domestic output per efficiency

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[28] Actual model simulations assume that the private sector intratemporal budget constraint (equation (3)) is the redundant budget constraint by Walras' Law, hence it is excluded from the set of model equations. (Obviously the intertemporal budget constraint is still used in deriving optimal private consumption levels). Hence fbp is the endogenous variable associated to the external sector budget constraint (2).

labor force unit is 1.0, all exogenous variables can be interpreted as ratios to initial steady-state output. Both the public and private sector benefit from foreign transfers, at 0.015 each. Foreign income is normalized at 1.0. Foreign direct investment flows amount to 0.005. Public indebtedness in foreign and domestic capital markets is 0.30 and 0.20, respectively. The sum of public consumption and investment is 0.19, with a relatively large share of consumption. All absolute foreign price indices are normalized at 1.0, with zero foreign inflation. The rate of growth of the labor force in efficiency units is equal to the sum of population growth (2%) and the rate of Harrod-neutral technical progress (1%). The foreign real (and nominal) interest rate is 6%. Finally, nominal base money grows at 5%.

The initial steady-state values of endogenous variables for the NC economy (and of most endogenous variables for the K)[29] are reported in Table 4. Initial (and final) steady-state output growth is determined by the rate of growth of the labor force in efficiency units (3%). Hence output per efficiency labor is constant; parameter values were chosen so that its numerical value is 1.0.

At the initial steady-state equilibrium, total private sector (or consumer) wealth is almost 20 times output, corresponding to the sum of non-human wealth (4.990) and human wealth (14.417). The four components of non-human wealth (other than the exogenous public debt) are domestic base money (0.15), the domestic-currency value of foreign assets (0.874), the net value of equity given by the product of q (0.6) and the difference between the total capital stock (3.0) and the equity owned by foreigners (0.115), and minus the present value of costs derived from holding base money (0.4).

Steady-state inflation at 2% is given by the difference between money growth and output growth. Seigniorage is defined as the product of base money holdings and its rate of growth. At initial and final steady-state equilibria, seigniorage is 0.75% of output -- the amount required to finance an operational public sector deficit of the same magnitude. Note that only at steady-state positions seigniorage is equal to the sum of the inflation tax (0.3% of output) and the growth effect on money demand (0.45% of output). At non-stationary equilibria, accumulation of money holdings drives a wedge between seigniorage and the latter sum.

Initial steady-state private consumption is 0.58, mostly comprised by national-goods consumer spending. Stationary gross domestic investment is 0.21, all of which goes to replace depreciated capital per efficiency labor force unit. 60% of investment falls on domestically-produced goods. Investment adjustment costs are zero at the steady state, because they are only incurred on net investment. Exports are 0.20, intermediate imports are 0.10, and total imports reach a level of 0.242. The corresponding trade deficit of 0.042 and profit remittances (0.01) are financed by foreign transfers (0.03), the net return (net of growth) on foreign-held assets, which yields 0.017, and direct foreign investment flows (0.005). The latter flow finances an initial current account deficit (net of accumulation of foreign assets to maintain constant asset/output ratios) of 0.005.

The steady-state nominal interest rate of 8% equals the sum of long-run domestic inflation and the real interest rate. At a real exchange rate of 1.0, all relative goods prices are also equal to 1.0. The

[29] As discussed in section 3.1, Tobin's q is higher and investment is lower under binding liquidity constraints than in the neoclassical economy. In fact, initial steady-state values in the K economy are 1.479 for q and 0.208 for gross domestic investment, which can be compared to the stationary values in the NC economy, reported in Table 4. The stationary capital stock is slightly lower in the K economy (2.973), but the total equity value (q times k) is larger. Higher equity more than offsets lower foreign assets held by the private sector (equal to 0.853 in the K economy). Hence steady-state total consumer wealth and consumption are slightly larger in the K economy. The stationary trade deficit is slightly lower in the K economy, as the return on foreign asset holdings has slightly deteriorated due to the lower stock of private foreign asset holdings. All other variables remain unchanged in the K economy as compared to the NC case.

price of equity in units of national goods (q) is 1.444. Having normalized employment at 1.0. and with a labor share in production of 0.6, the real product wage is also equal to 0.6.

TABLE 2: PARAMETER VALUES FOR SIMULATIONS

Base money demand	ϕ_1 = 0.16, ϕ_2 = 1, ϕ_3 = -0.5
Wage setting rule	ω = 1,000 (NC) or 0.25 (K), Θ = 1.0 (NC) or 0.5 (K)
	α_0 = 0.91, α_1 = 0.6, α_2 = 0.3
Production function	μ = 2.5
Investment adjustment costs	δ = 0.04
Physical capital depreciation rate	β_1 = 1.0 (NC) or 0.5 (K), β_2 = 0.5
Private investment demand	γ = 0.6
Domestic content of investment	λ_1 = 1.0 (NC) or 0.5 (K), λ_2 = 0.06
Private consumption demand	η = 0.9
Domestic content of consumption	ρ_1 = 0.2, ρ_2 = 1.5, ρ_3 = 1
Export demand	

TABLE 3: INITIAL VALUES OF EXOGENOUS VARIABLES

Income, Transfer and Capital Flows	
Foreign transfer to public sector (ftrg)	0.015
Foreign transfer to private sector (ftrp)	0.015
Foreign income (yf)	1.0
Foreign direct investment (dfi)	0.005
Stocks	
Domestic debt of public sector (bg)	0.2
Foreign assets held by public sector (e fbg)	-0.3
Goods Flows	
Public national-goods consumption (cnp)	0.15
Public investment subsidy (ig)	0.04
All Foreign Price Levels	1.0
Rates	
Population growth (pg)	0.02
Harrod-neutral technical progress (tg)	0.01
Foreign real interest (rf)	0.06
Nominal base money growth (nmg)	0.05

TABLE 4: INITIAL STEADY-STATE VALUES OF ENDOGENOUS VARIABLES

Income, Capital and Transfer Flows	
Operational profits (op)	0.300
Dividends paid (d)	0.260
Taxes (td)	0.183
Private disposable income (yd)	0.433
Profit Remittances (prem)	0.01
Stocks	
Total private sector wealth (a+hu)	19.407
Non-human wealth of private sector (a)	4.990
Stock of domestic equity held by foreigners (fe)	0.115
Domestic base money (hb)	0.15
Human wealth of private sector (hu)	14.417
Physical capital (k)	3.0
Present value of government investment subsidy (pvig)	1.233
Present value of cost of holding money (pvihb)	0.40
Foreign assets held by private sector (e fbp)	0.874
Goods Flows	
Private aggregate consumption (cp)	0.582
Private imported-goods consumption (cmp)	0.058
Private national-goods consumption (cnp)	0.524
Gross domestic investment (inv)	0.210
Private national-goods investment (in)	0.126
Private imported-goods investment (im)	0.084
Investment adjustment costs (iac)	0
Exports (x)	0.20
Intermediate imports (mr)	0.10
Total imports (mr)	0.242
Trade balance	-0.042
Current account balance	-0.005

Employment (l)	1.0
Output (y)	1.0
Rates	
Nominal interest rate on public debt (i)	0.08
Real interest rate on public debt (r)	0.06
Inflation rate	0.02
All Relative Goods Prices	1.0
Other Prices	
Real equity price (Tobin's q)	1.444
Real wage per effective labor unit	0.6
Real exchange rate (e)	1.0

The simulations below explore three alternative types of shocks: a permanent unanticipated (P) disturbance (hitting the economy from period 1 to terminal period T), a transitory unanticipated (TU) shock (hitting during periods 1-4), and a transitory anticipated (TA) shock (hitting during periods 2-5).

The simulations examine the effects of a fiscal expansion reflected by a public consumption increase of 4% of initial output. Three alternative forms of financing are considered: lump-sum taxation (a balanced-budget fiscal expansion), debt-financing, and monetary-financing.

The discussion of the simulation results focuses on the deviations from an initial steady-state equilibrium (represented by period 0), distinguishing between the impact effects (in period 1) and the transition toward the new steady-state equilibrium (from period 2 to terminal period T). The discussion is based on the figures depicting the dynamic paths of the main endogenous variables. For the tax-financed fiscal expansion, each figure page is divided into an upper panel, which reports the dynamic trajectories under the three types of shocks (P, TU, and TA) for the Neoclassical case, and a lower panel depicting the dynamic trajectories of the same shocks for the same variable in the Keynesian case. Because Ricardian equivalence holds in the NC economy, the response of the key variables is the same regardless of the financing alternative chosen. Thus, for the debt-financed case, we show the dynamic trajectories of four variables for the K case only. For the money-financed case, we show the dynamic trajectories of three variables for the NC economy and nine variables for the K economy. The terminal period T varies between 70, 80, and 90 periods.

4.2 A Balanced-Budget Fiscal Expansion

Under a balanced-budget expansion, taxes are raised to finance higher government consumption and any other net expenditure increase arising endogenously, such as higher interest payments on the domestic public debt. The dynamic paths of the main endogenous variables in response to the tax-financed fiscal expansion are shown in figures 1-10.

Consider first the neoclassical (NC) economy and the case of a permanent tax-financed fiscal expansion. Tax revenue increases by 4 percentage points (pp.) of output in period 1 and thereafter (Fig. 1). A permanent increase in government consumption and taxes reduces wealth and private consumption accordingly (Fig. 2). Recall that public consumption falls entirely on national goods while private consumption falls on both national (90%) and imported goods (10%). Hence the tax-financed increase in government consumption causes an expenditure switch from imported to national goods, appreciating the real exchange rate in period 1 (Fig. 3). This in turn induces a second decline in consumer wealth, as the private sector, which holds net foreign assets, suffers a capital loss. The total effect on private consumption is a reduction of 4 percentage points of output, already achieved in period 1. The impact effect on output is positive, stemming from the expenditure switch toward national goods (Fig. 4). This aggregate demand increase is satisfied by using more intermediate imports in production, in response to their lower domestic-currency price as a result of the real exchange rate appreciation. Further output gains are observed during the transition toward the new steady-state equilibrium, as aggregate supply is increased by capital accumulation. Steady-state output exceeds initial output by 0.3%.

After the initial appreciation, the real exchange rate depreciates slightly toward its new steady-state level, which shows an appreciation of 0.8% from the initial steady-state. Covered interest arbitrage implies a one-to-one relation between the real interest rate and the rate of anticipated depreciation of the real exchange rate. Because the real exchange rate trajectory is almost flat, so are both the real interest rate (Fig. 5) and Tobin's q. The decline in the real price of capital goods due to the real appreciation is sufficient to promote an investment increase, by 0.2 pp. of output in the first period, and then declining toward the new steady-state level, which exceeds the initial investment ratio by 0.1 pp. of output (Fig. 6). The result is higher steady-state capital.

The adjustment is characterized by a temporarily higher current account deficit due to the increase in investment (Fig. 7). Since the economy is already at full employment, the increase in output and subsequent higher demand for labor leads to a higher real wage, whose steady-state value exceeds its initial value by 0.3% (Figs. 8 and 9).

Now consider a temporary balanced-budget expansion. It induces a U or inverted U-shaped responses of most endogenous variables in a NC economy. The reason is that while private consumers reduce aggregate consumption only marginally when the shock is temporary, public consumption increases for four periods by the full 4% of initial output. Hence, aggregate demand increases significantly during those 4 periods, raising the current account deficit temporarily by about 1 pp. of output.

The temporary increase in aggregate demand for national goods induces a strong real exchange rate appreciation (by 3.5%) during the 4-period fiscal expansion (Fig. 3). The temporary current account deficit, financed entirely by the private sector running down its foreign assets, reduces total private sector wealth. Hence, in contrast with the case of a permanent fiscal expansion, steady-state output and investment are <u>lower</u> than in the initial steady state, and the real exchange rate is depreciated (Figure 4). Real wages mimic the pattern of output, with the new steady-state level also below the initial level (Figure 9).

The temporary real appreciation causes abrupt impact and anticipated future changes in the real interest rate (Figure 5). Now the anticipated rise in interest rates dominates the decline in imported capital goods prices and hence investment suffers a slump. The decline in the capital stock causes a declining output pattern after the first-period expansion. In the TA case, the real interest rate falls in period 1 (unlike in the TU case) because of the anticipated appreciation.[30]

Consider now the Keynesian (K) economy. Apart from the over-employment peak of 0.25% in period 2, the similarity of the effects of a permanent shock in this economy to those of a permanent shock in the NC economy justifies proceeding immediately to discuss the more interesting results of temporary shocks. Recall that in the K framework, nominal wages are indexed to current and lagged consumer price inflation. The introduction of liquidity-constrained (or myopic) consumers and firms (50% of each group), combined with the sluggish wage adjustment and associated employment fluctuations, exacerbates the response of consumption and output, and dampens the response of all other endogenous variables to a temporary fiscal expansion, as compared to the NC economy. More specifically, output expands more than in the NC economy due to the higher employment, while the real exchange rate appreciates less due to the aggregate supply increase. The lower consumption and higher investment in the K model result in a current account deficit similar to the NC case.

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[30]The decline in the real interest rate in period 1 of the TA case causes a drop in the tax revenue required for period 1 because the interest payments on pre-existing government debt have fallen. The opposite is true in period 4 (TU case) and period 5 (TA case). For both the TU and TA cases, tax-revenue peaks at 4.5 percentage points above the initial steady-state level, and then returns to its initial level immediately after the shock disappears. The same intuition applies below when considering movements in the real interest rate and debt stock in the debt-financed case, and movements in the real interest rate and seignorage (and money/output) in the money-financed case.

Liquidity constraints reduce consumption, in response to temporary tax hikes, by more than the consumption reduction of non-constrained or Ricardian consumers. This implies that there is a stronger private offsetting of the temporary public consumption surge than in the NC economy, and hence a weaker real exchange rate appreciation and weaker fluctuations in the real interest rate.

There is also a weaker response of every other endogenous variable, both during the temporary 4-period span and beyond, whereas the new steady-state values are similar to those in the NC economy. The wage behavior is dampened in comparison to the NC economy, giving rise to large cyclical employment fluctuations, with an employment and output boom in periods 1-4 when the shock is temporary unanticipated (TU) or in periods 2-5 when the shock is temporary anticipated (TA), and an employment and output decline of similar amplitude during periods 5-8 (TU) or 6-9 (TA). Employment now exhibits a complete cycle, as opposed to the P shock. The most pronounced cycle is in the case of the TA shock. Over-employment is 0.8% in period 2, shrinking afterwards to reach an under-employment maximum of 0.7% in period 6, before starting asymptotic convergence toward the full employment steady-state (Fig. 8).

4.3 A Debt-Financed Fiscal Expansion

Regardless of the structure of the economy (NC or K), it is not sensible to consider a permanently debt-financed fiscal expansion, because this would violate the government's solvency condition. Hence only a transitory expansion is considered, financed with debt while it lasts, after which the financing method is again taxes.

However, a debt-financed expansion has identical effects to a tax-financed expansion in a NC economy due to Ricardian equivalence. Debt-financing merely postpones taxation, and therefore is equivalent to current taxation. Hence, only TU and TA debt-financed fiscal expansions for a K economy need to be considered.

Domestic debt increases from 20% to 38.5% of output, reflecting temporary debt financing during periods 1-4 in the TU case or 2-5 in the TA case (Fig. 11). The dynamic response is now much stronger than under tax-financing in a K economy (Figure 12). The reason is that constrained consumers do not reduce their consumption in response to debt-financing like they did under tax-financing. The magnitude of the effects is roughly twice those under tax-financing. Output in particular displays the same pattern and cycle here as in the tax-financed case, but the peak and trough of the cycle are much more pronounced.

4.4 A Money-Financed Fiscal Expansion

The growth rate of the money stock (nmg) is endogenous under money-financing. By raising seignorage to finance its temporary consumption spree, the government taxes more heavily base money holdings through inflation; by contrast, conventional taxes and debt remain at their initial levels under this financing alternative.

In the NC economy, Ricardian consumers are indifferent among tax, debt, or money-financed fiscal expansions. Nevertheless, the trajectory of inflation and money holdings are affected. Consider a permanent shock in the NC economy. At the initial steady-state, nmg was growing at 5% -- 2% to account for inflation and 3% for output growth. With the public expenditure boom, seignorage must increase to 4.8% of output -- the initial steady-state level of seignorage was 0.8% and the fiscal expansion requires additional financing by 4% of output (Fig. 13). In order to raise sufficient seignorage, given the assumed parameters of the money-demand schedule, the government must raise the growth rate of money to 37%, which implies long-run inflation of 34%, as steady-state output growth remains at 3% (Figs. 14 and 15).

Consider now the temporary cases of money-financed public consumption in a NC economy. A major result is that, immediately after the initial inflation jump to 14%, inflation begins to fall and money balances begin to rise, to converge smoothly toward their final steady-state levels. The reason behind this instantaneous adjustment of money holdings and inflation is the rational anticipation of the end of the fiscal expansion so that potential capital gains at the beginning of periods 5 (TU shock) or 6 (TA shock), which would result from an abrupt decline in inflation, are ruled out.

Now let's turn to the K economy. What becomes apparent in this case is that a massive, endogenous aggregate supply response outweighs the exogenous aggregate demand shock, causing a real exchange rate depreciation. Aggregate supply grows strongly due to the partial indexation of nominal wages to lagged consumer price inflation. In all three cases (P, TA, and TU), the real wage falls substantially during the first 2 periods, when inflation is rising rapidly. Thus a large increase in employment and output is observed because labor is very cheap (Figures 16-17). Consider the TU policy. Beginning in period 3, real wages begin to rise in response to higher lagged inflation, now inducing an aggregate supply slump, which causes employment and output to contract. Employment, which peaks in period 2 at an 18% level of over-employment, shrinks to a trough of 12%, in period 6, after which it converges asymptotically to its new stationary level. The same pattern is observed in the case of output, with a peak of 11.5% above the initial steady-state and a trough of 8% below the initial steady-state.

In all three types of shocks, the real interest rate and the real exchange rate exhibit much more fluctuation than in the tax-financed Keynesian case or the NC case (Figure 18). The reason is the strong role of nominal inertia in the face of rapid inflation, which causes sharp cycles. This is particularly true in the TA case, where in period 1 the real interest rate falls 2 percentage points, then increases 9 percentage points between periods 1 and 2, falls almost 11 percentage points between periods 2 and 3, and continues in such a manner until convergence. Similarly in the TA case, the real exchange rate fluctuates widely, reaching a peak in period 3 at 5 percentage points above the initial level, and reaching a trough in period 7 that is 6 percentage points below its initial level.

Similar to the NC case, inflation in the cases of temporary shocks begins to decline to the original steady-state level before the temporary shocks stop, in order to rule out any anticipated capital gains when fiscal policy, inflation, and money abruptly return to their initial levels.

5. CONCLUDING REMARKS

This paper has developed a dynamic macroeconomic general equilibrium model for two economies: a neoclassical case with frictionless, instantaneous clearing in goods, assets, and labor markets, and a Keynesian case with groups of liquidity-constrained agents and wage rigidity, giving rise to temporary deviations from full-employment. The model has been applied to simulate the impact, transitional, and steady-state effects of permanent, temporary unanticipated, and temporary anticipated fiscal expansions.

Though it shares forward-looking behavior based on microanalytical foundations with other models, this model is in many ways very distinct. It includes several realistic features that are relevant for most open economies. Three of those features have been highlighted in this paper: nominal wage rigidity, import content of capital goods, and monetary finance of budget deficits. The model also highlights the short and long-term consequences for private consumption and investment of liquidity constraints. In the simulations, the full non-linear model is solved, rather than the conventional procedure that uses linear approximations.

Both permanent and transitory fiscal expansions result in long-run changes in output, the real wage, the real exchange rate, and investment in the NC economy. Ricardian equivalence guarantees the same response of real variables to the fiscal expansion, whether the increase in public consumption is financed by current taxation, debt, or money.

In the K economy, however, wage rigidities and liquidity constraints generate cyclical adjustment to the fiscal expansions. For the tax-financed case, the parameters of the K economy exacerbate the adjustment patterns of consumption and output, while dampening the response of the other endogenous variables relative to the NC case. The dynamic response of some key variables in the debt-financed case is roughly twice as large as that in the tax-financed case, as constrained consumers do not adjust their consumption as they did in the case of tax-financing. In the money-financed K case, a massive aggregate supply response outweighs the exogenous aggregate demand shock, due to the inertia of nominal wages. The result is a real depreciation and a very strong cyclical adjustment of output, the real wage, and employment.

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Figure 1

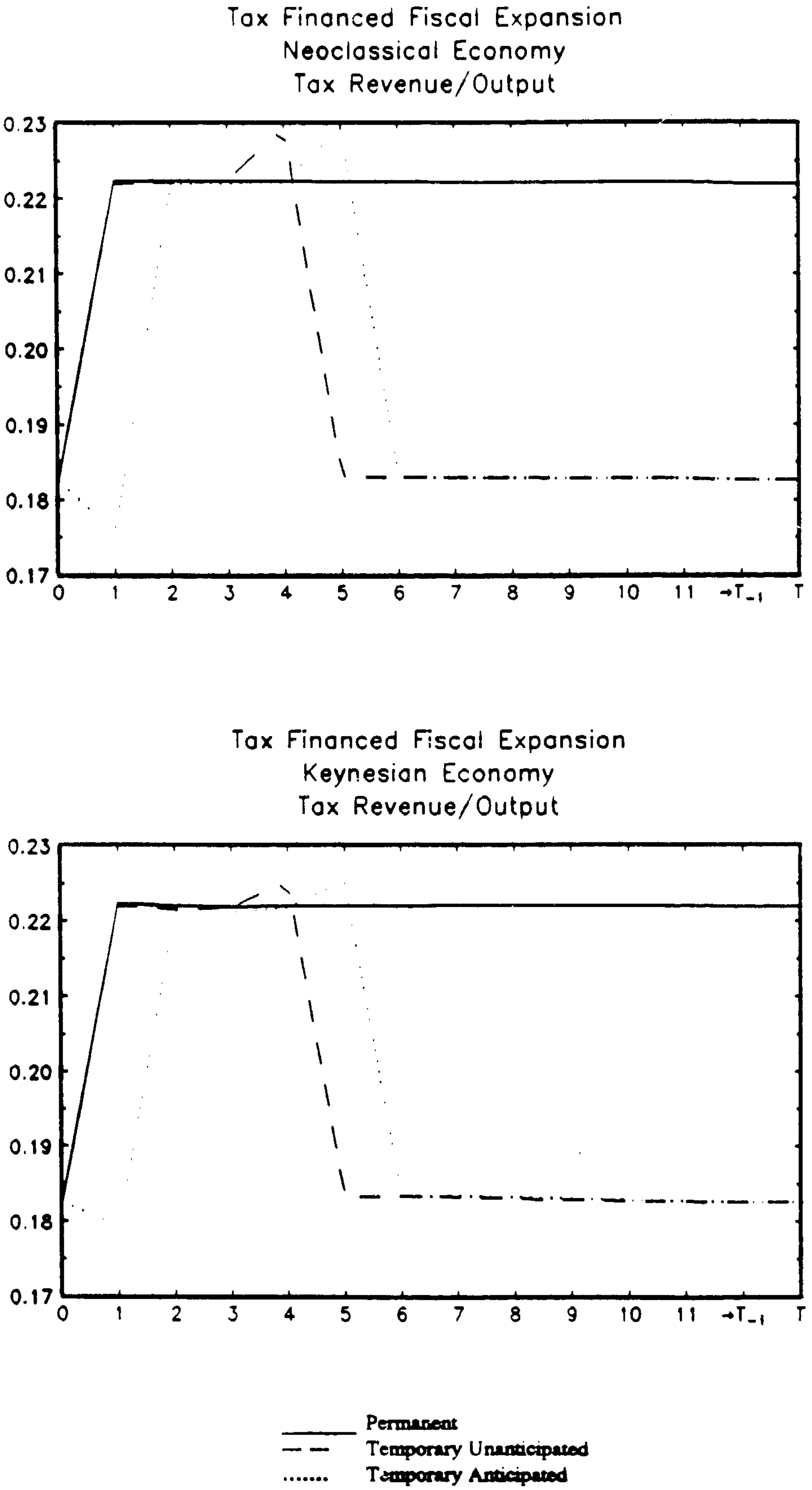

Tax Financed Fiscal Expansion
Neoclassical Economy
Tax Revenue/Output
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0 1 2 3 4 5 6 7 8 9 10 11 →T_{-1} T
Tax Financed Fiscal Expansion
Keynesian Economy
Tax Revenue/Output
0.23
0.22
0.21
0.20
0.19
0.18
0.17
0 1 2 3 4 5 6 7 8 9 10 11 →T_{-1} T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 2

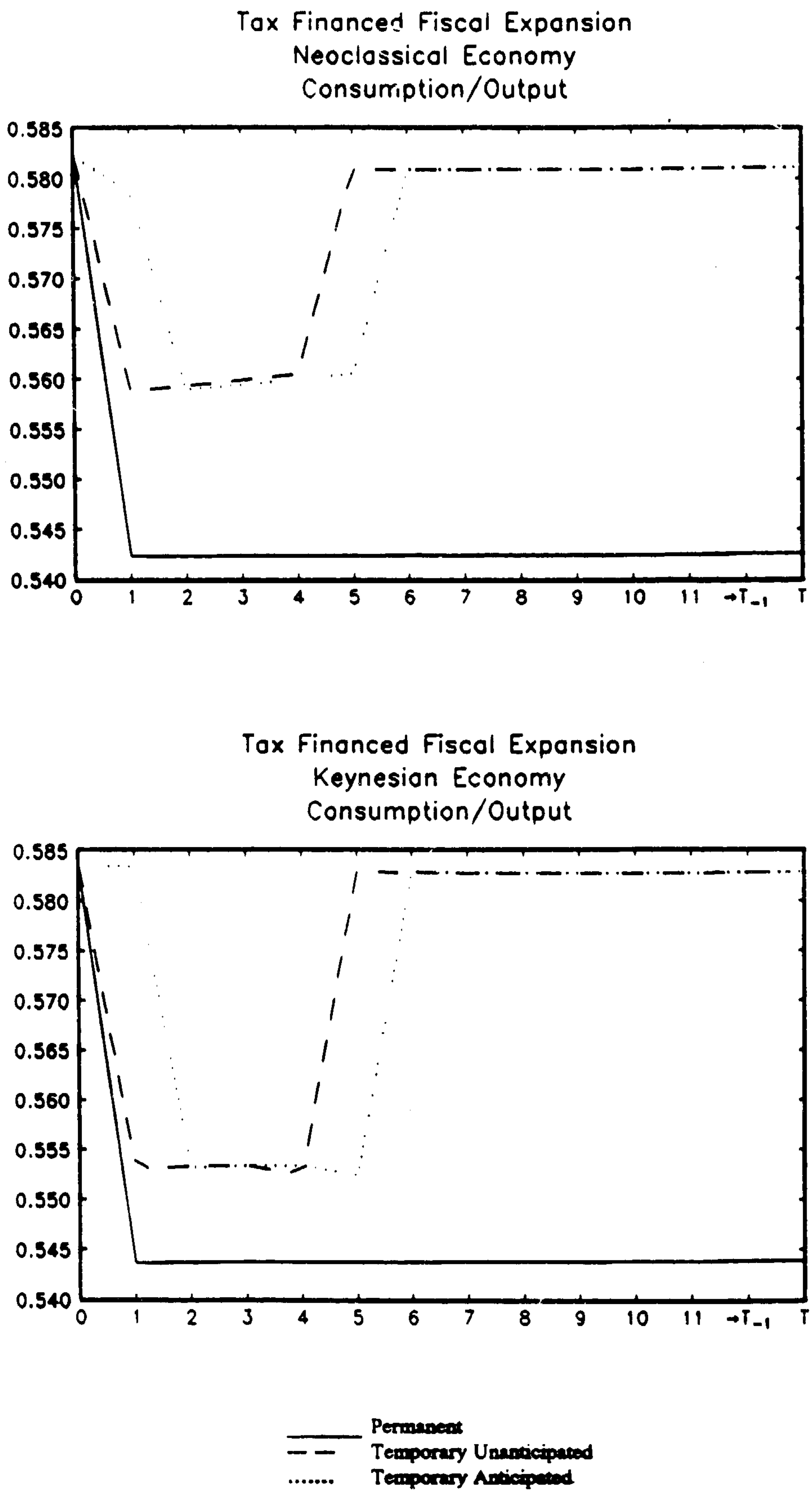
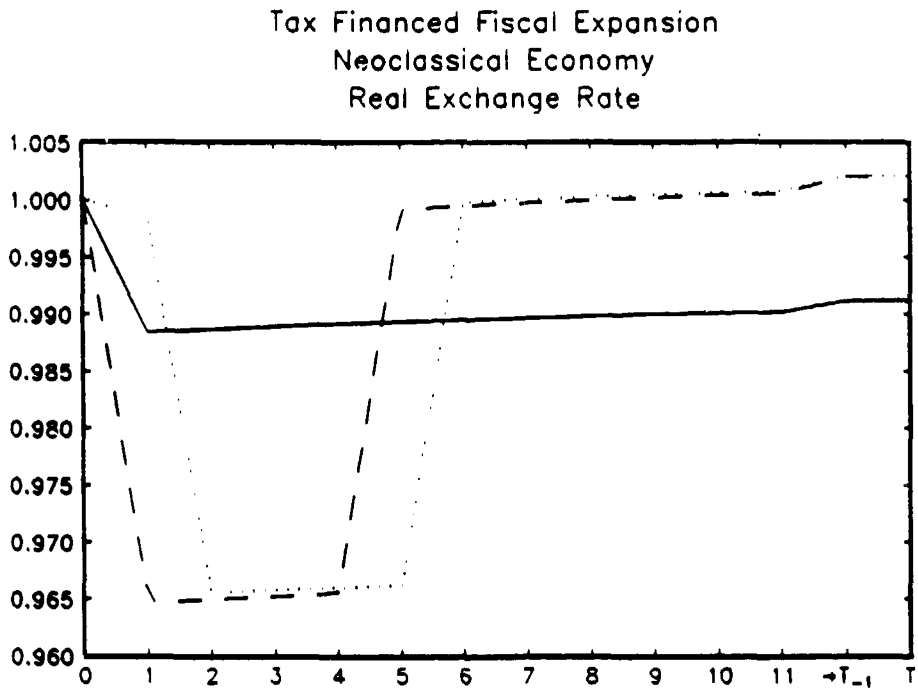

Tax Financed Fiscal Expansion
Neoclassical Economy
Consumption/Output
0.585
0.580
0.575
0.570
0.565
0.560
0.555
0.550
0.545
0.540
0 1 2 3 4 5 6 7 8 9 10 11 →T-1 T
Tax Financed Fiscal Expansion
Keynesian Economy
Consumption/Output
0.585
0.580
0.575
0.570
0.565
0.560
0.555
0.550
0.545
0.540
0 1 2 3 4 5 6 7 8 9 10 11 →T-1 T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 3


Tax Financed Fiscal Expansion
Neoclassical Economy
Real Exchange Rate
1.005
1.000
0.995
0.990
0.985
0.980
0.975
0.970
0.965
0.960
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T

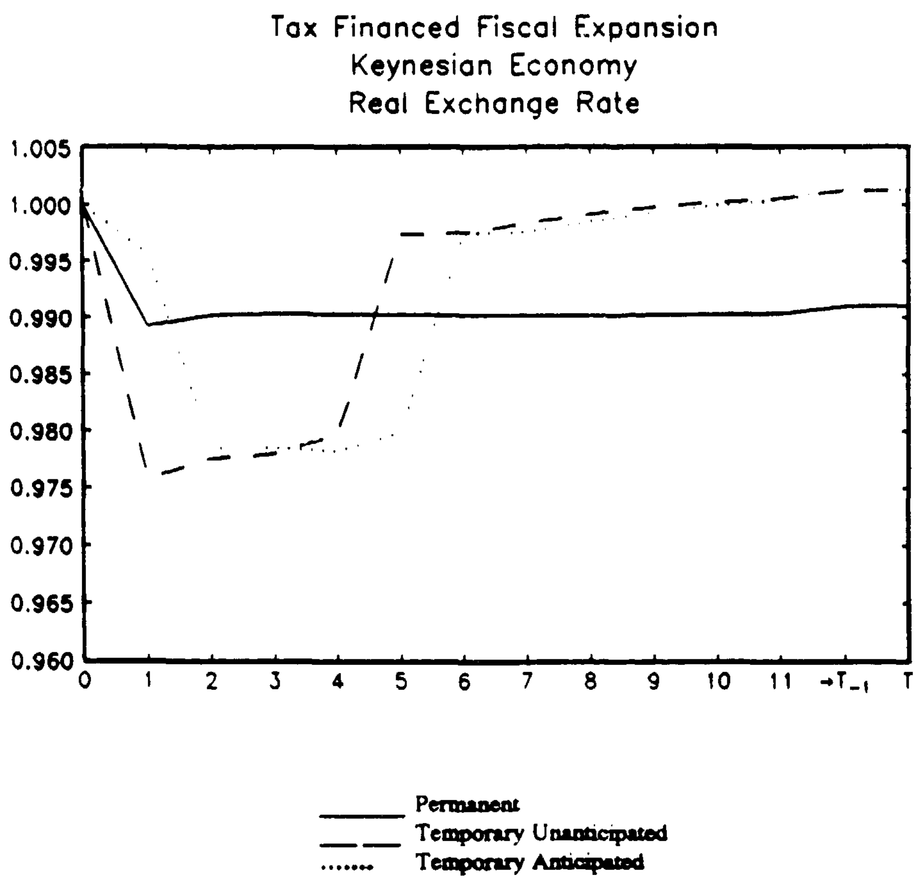
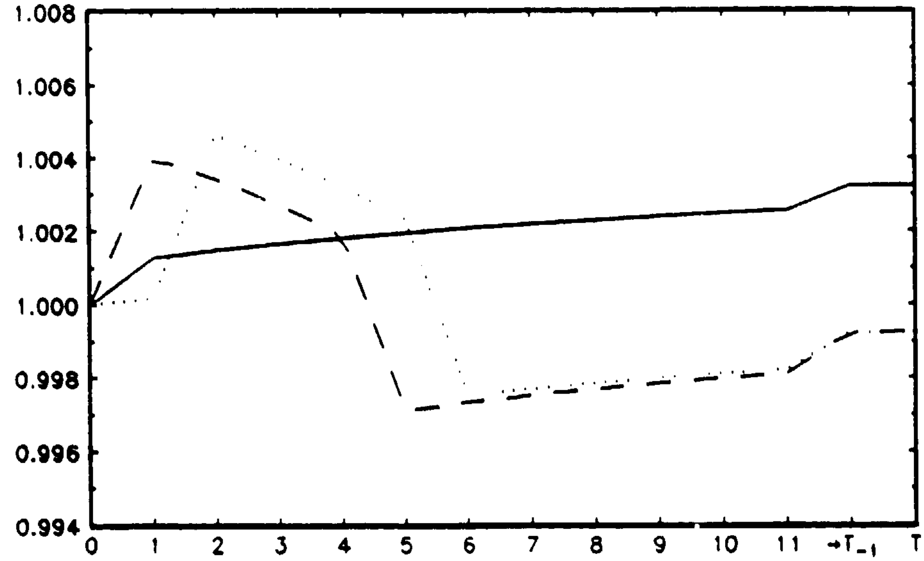
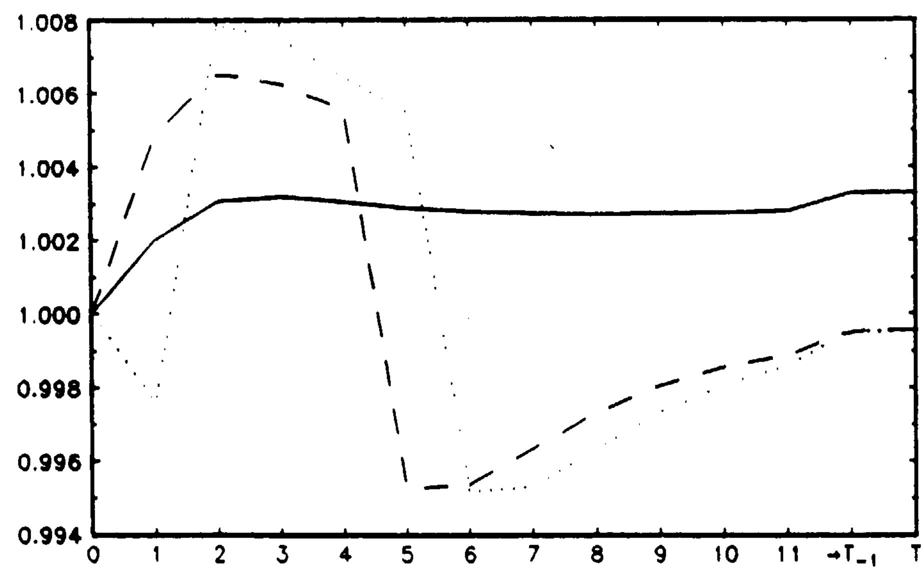

Tax Financed Fiscal Expansion
Keynesian Economy
Real Exchange Rate
1.005
1.000
0.995
0.990
0.985
0.980
0.975
0.970
0.965
0.960
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 4

Tax Financed Fiscal Expansion
Neoclassical Economy
Output

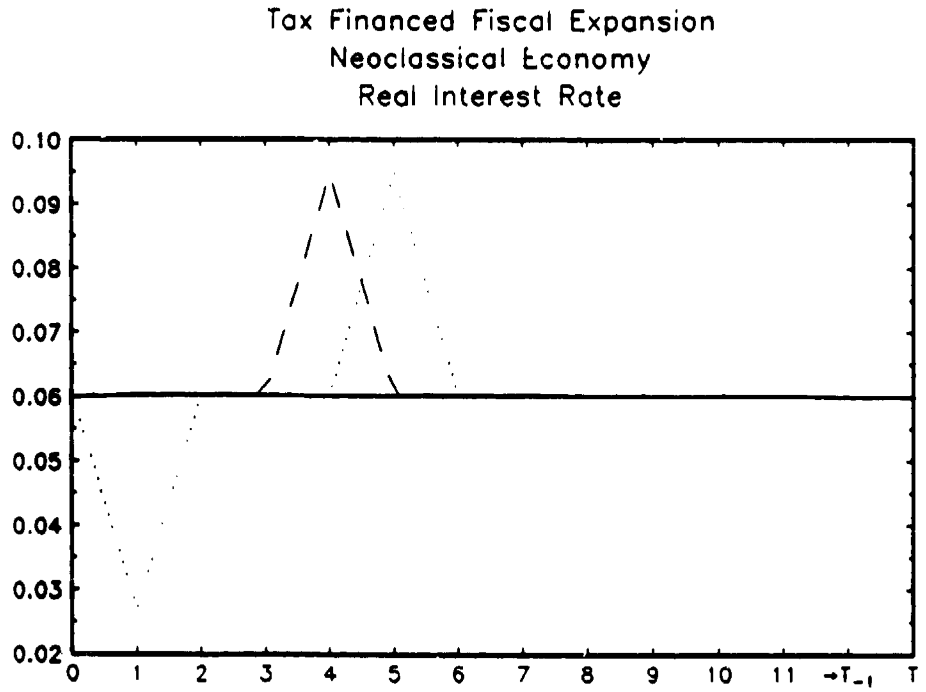


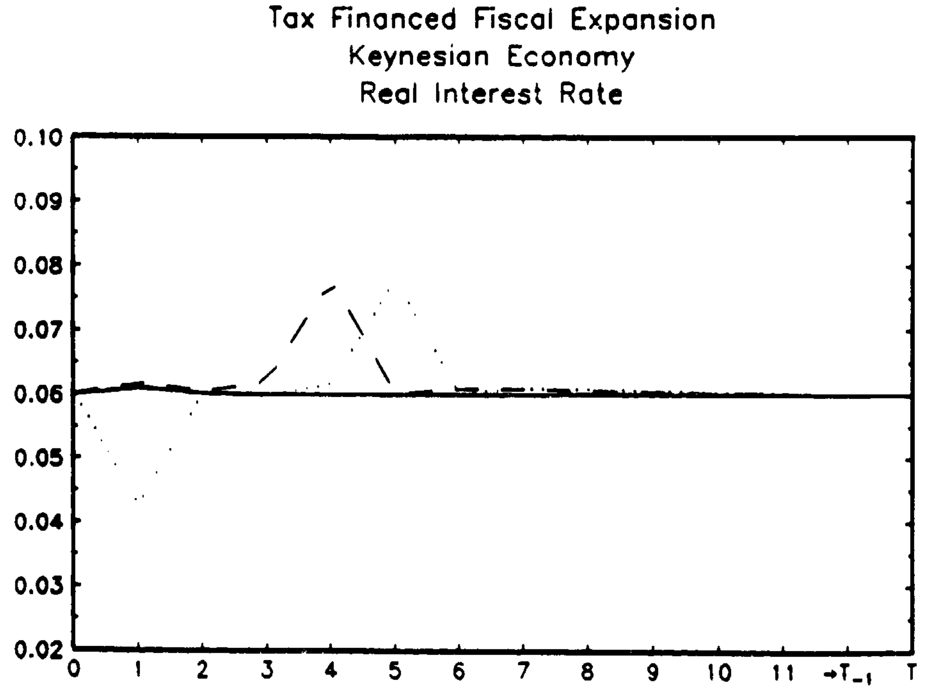
Tax Financed Fiscal Expansion
Keynesian Economy
Output



Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 5

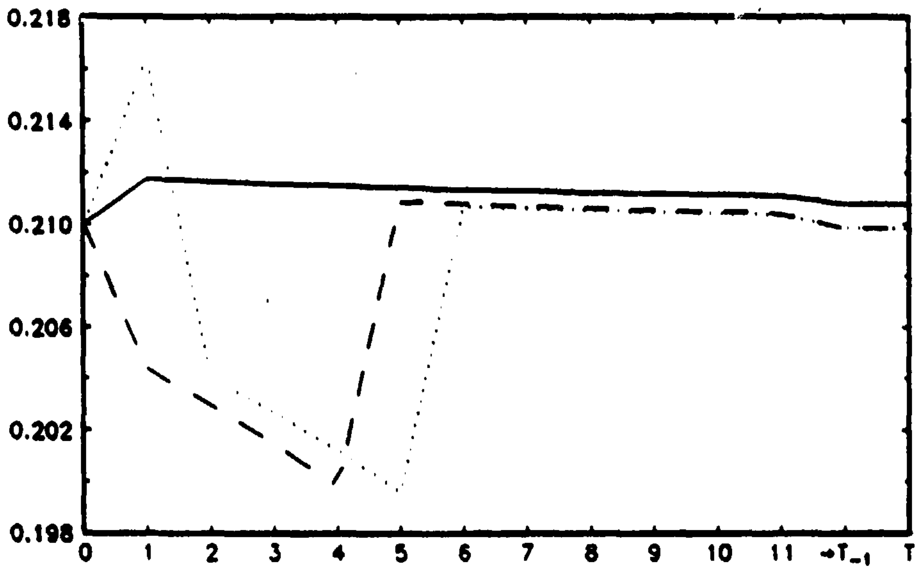




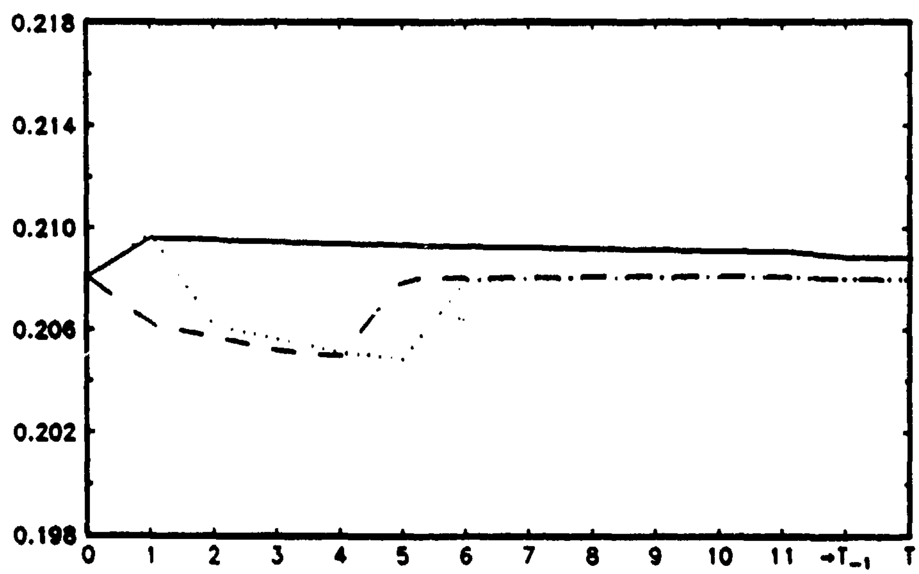
——— Permanent
— — Temporary Unanticipated
.... Temporary Anticipated

Figure 6

Tax Financed Fiscal Expansion
Neoclassical Economy
Investment/Output



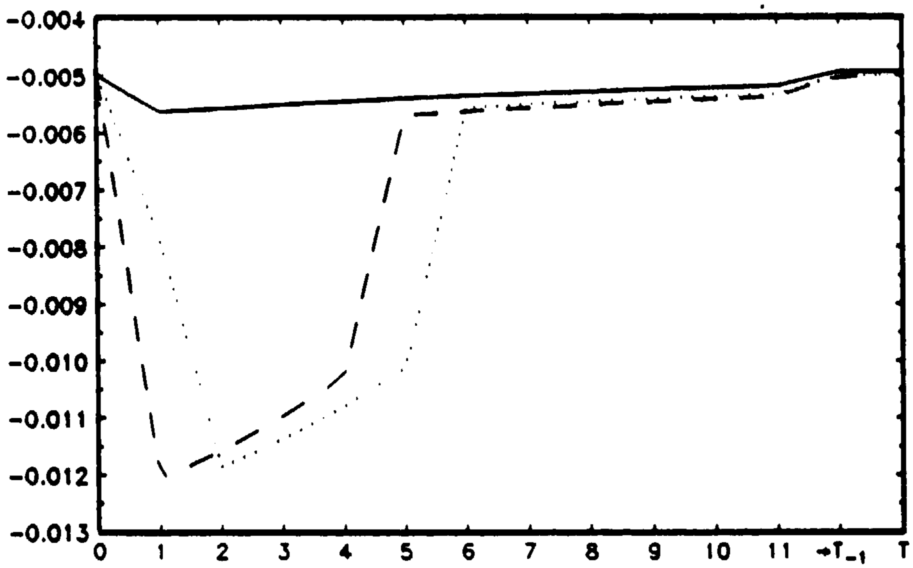
Tax Financed Fiscal Expansion
Keynesian Economy
Investment/Output



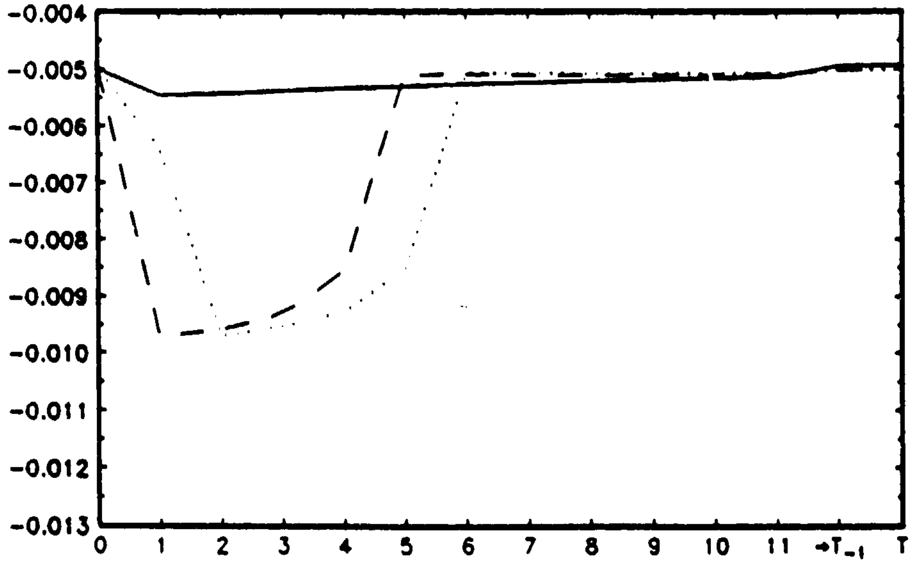
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 7

Tax Financed Fiscal Expansion
Neoclassical Economy
Cur Acc Bal/Output



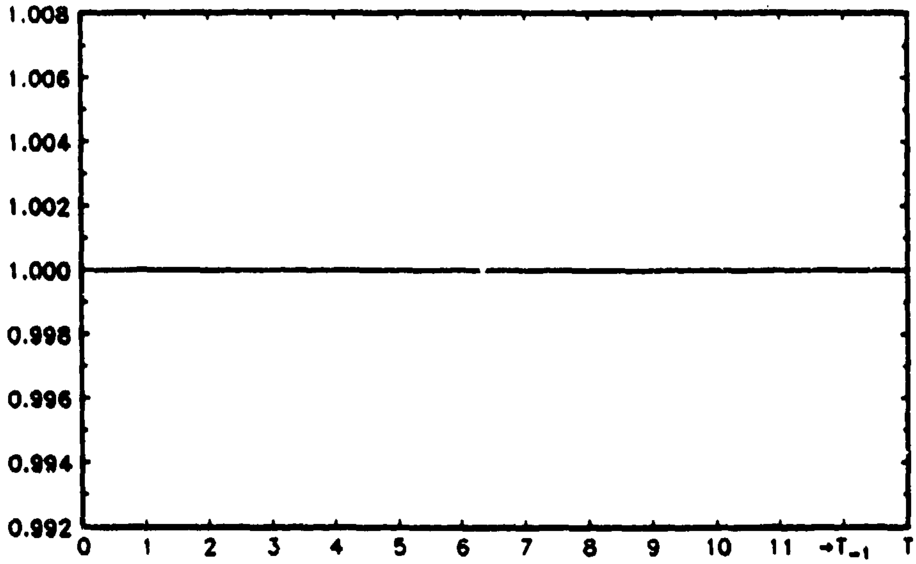
Tax Financed Fiscal Expansion
Keynesian Economy
Cur Acc Bal/Output



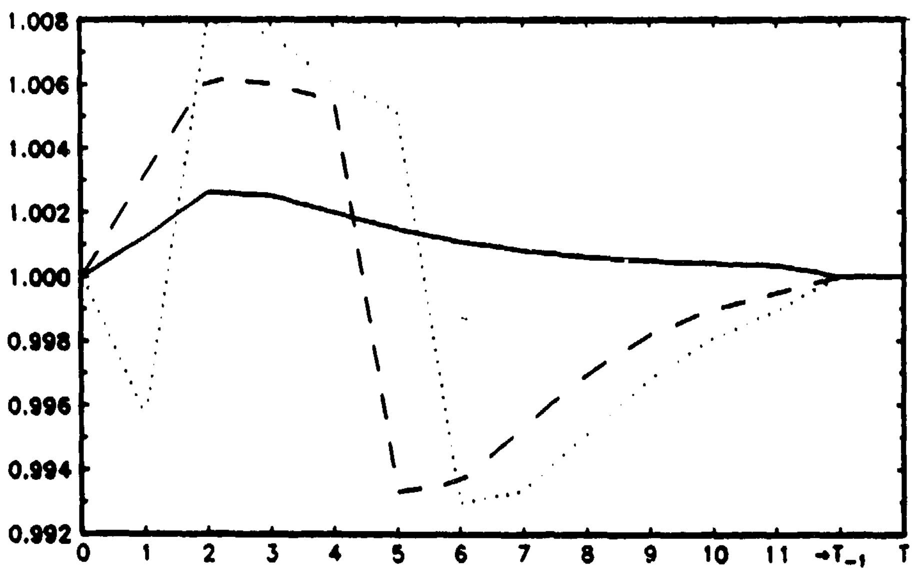
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 8

Tax Financed Fiscal Expansion
Neoclassical Economy
Employment



Tax Financed Fiscal Expansion
Keynesian Economy
Employment



Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 9

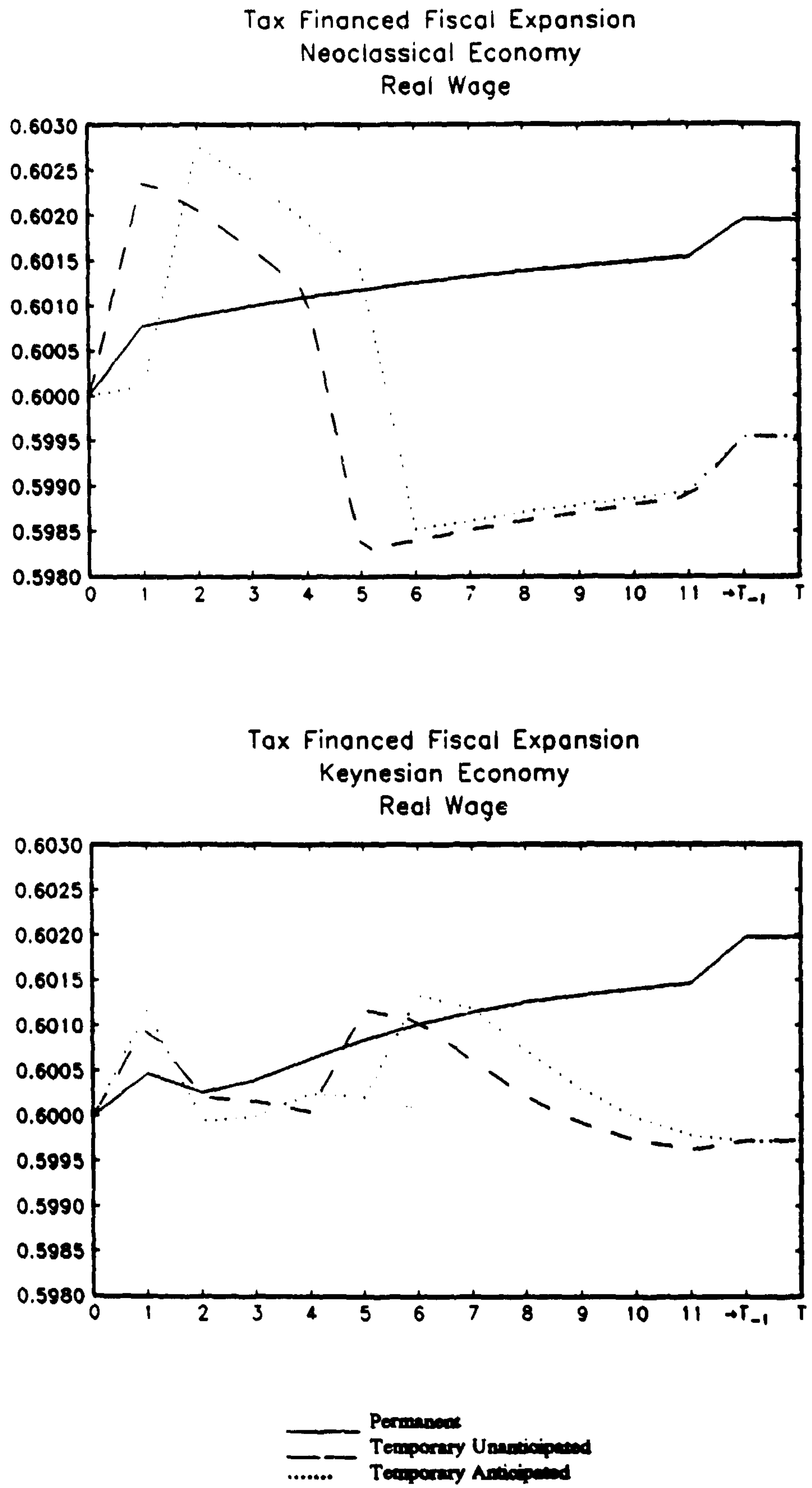
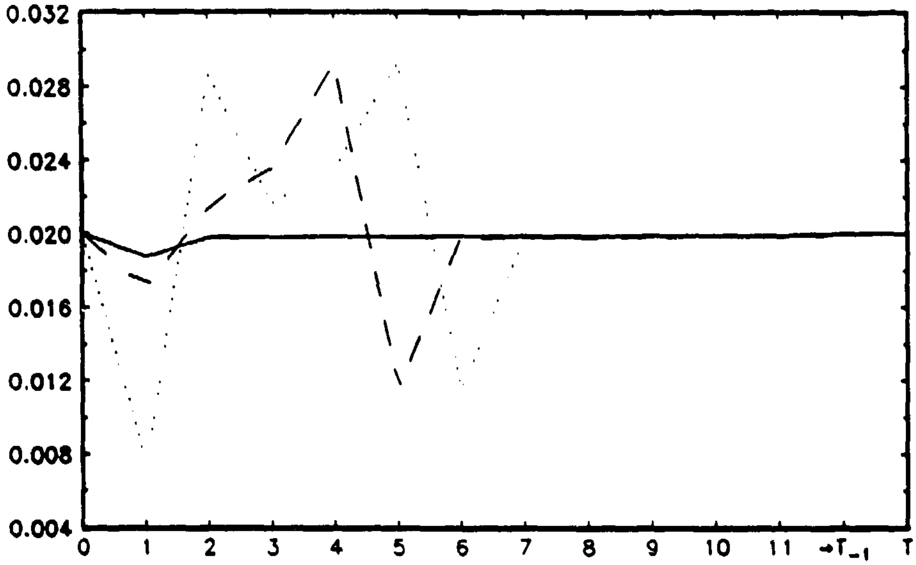
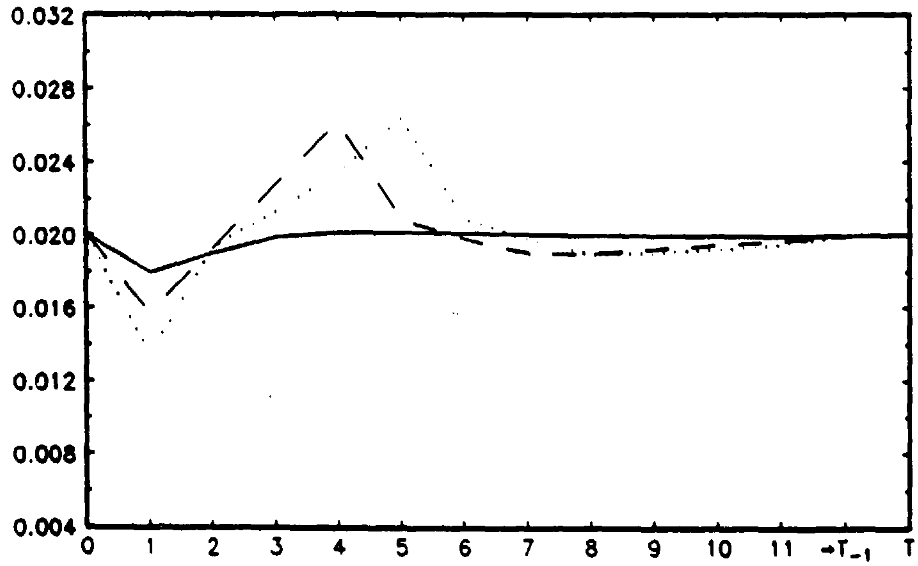

Tax Financed Fiscal Expansion
Neoclassical Economy
Real Wage
0.6030
0.6025
0.6020
0.6015
0.6010
0.6005
0.6000
0.5995
0.5990
0.5985
0.5980
0 1 2 3 4 5 6 7 8 9 10 11 →T-1 T
Tax Financed Fiscal Expansion
Keynesian Economy
Real Wage
0.6030
0.6025
0.6020
0.6015
0.6010
0.6005
0.6000
0.5995
0.5990
0.5985
0.5980
0 1 2 3 4 5 6 7 8 9 10 11 →T-1 T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 10

Tax Financed Fiscal Expansion
Neoclassical Economy
Inflation Rate

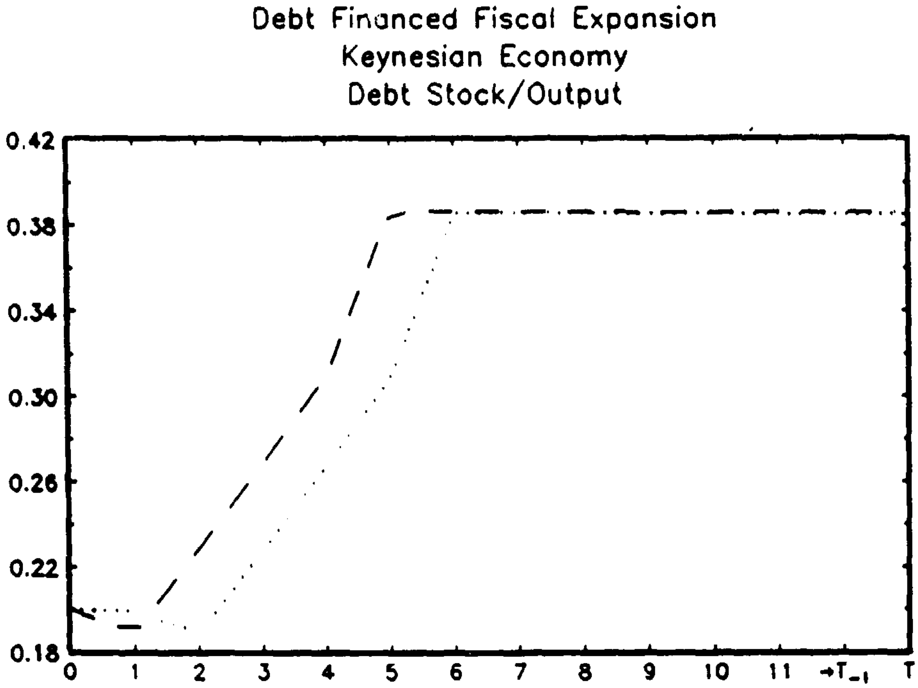


Tax Financed Fiscal Expansion
Keynesian Economy
Inflation Rate



______ Permanent
— — Temporary Unanticipated
.... Temporary Anticipated

Figure 11


Debt Financed Fiscal Expansion
Keynesian Economy
Debt Stock/Output
0.42
0.38
0.34
0.30
0.26
0.22
0.18
0
1
2
3
4
5
6
7
8
9
10
11
→T_{-1}
T

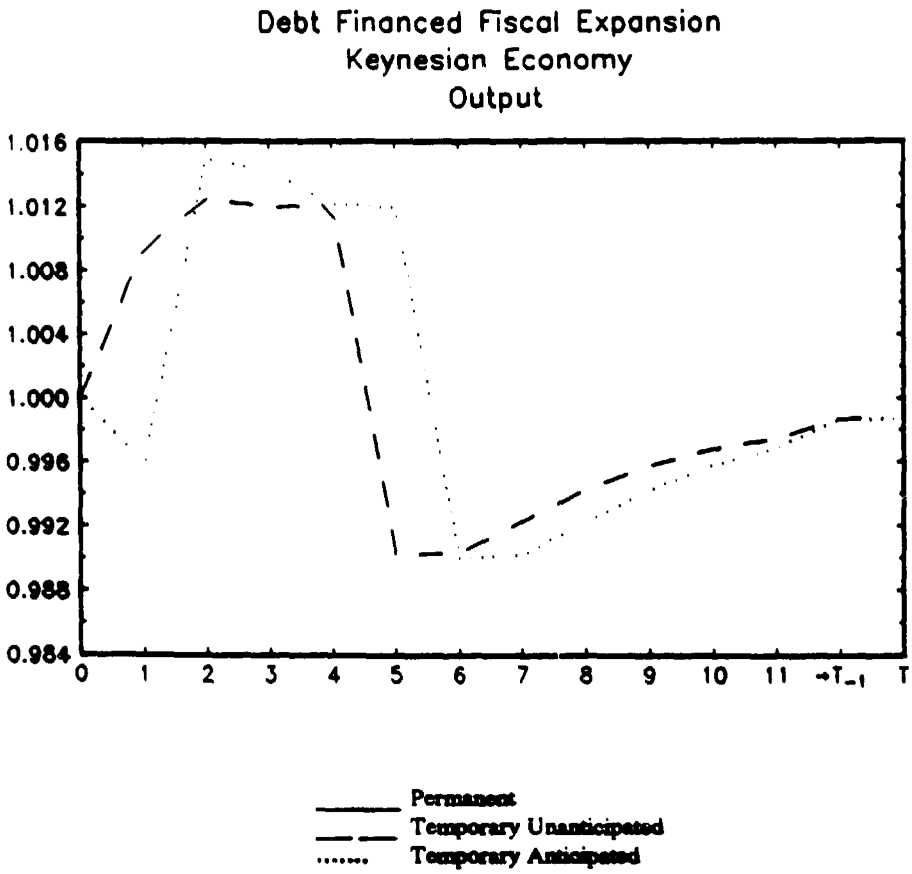
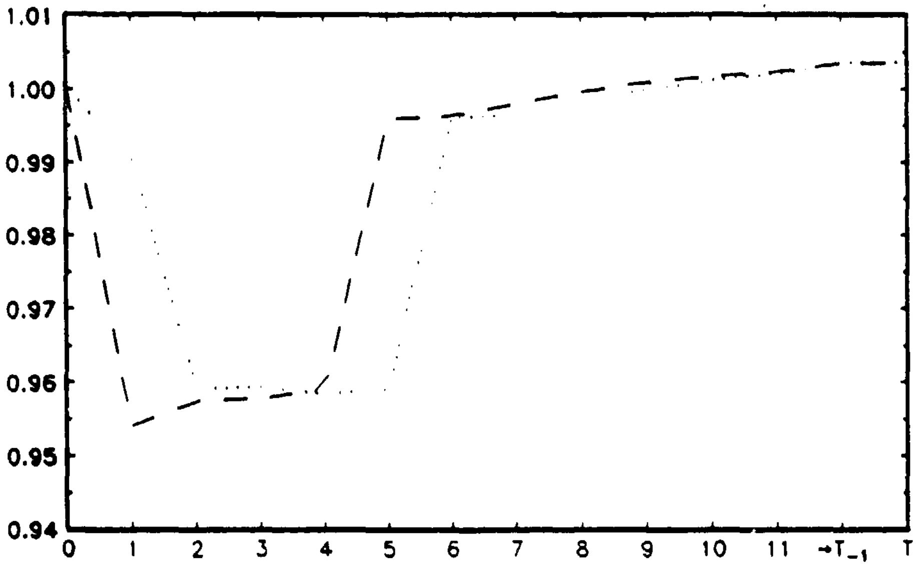
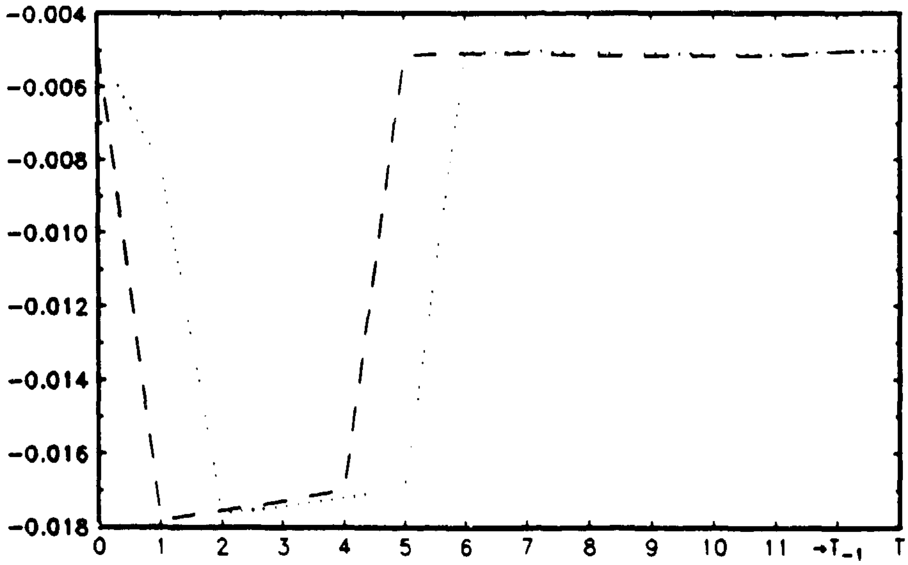

Debt Financed Fiscal Expansion
Keynesian Economy
Output
1.016
1.012
1.008
1.004
1.000
0.996
0.992
0.988
0.984
0
1
2
3
4
5
6
7
8
9
10
11
→T_{-1}
T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 12

Debt Financed Fiscal Expansion
Keynesian Economy
Real Exchange Rate



Debt Financed Fiscal Expansion
Keynesian Economy
Cur Acc Bal/Output



Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 13

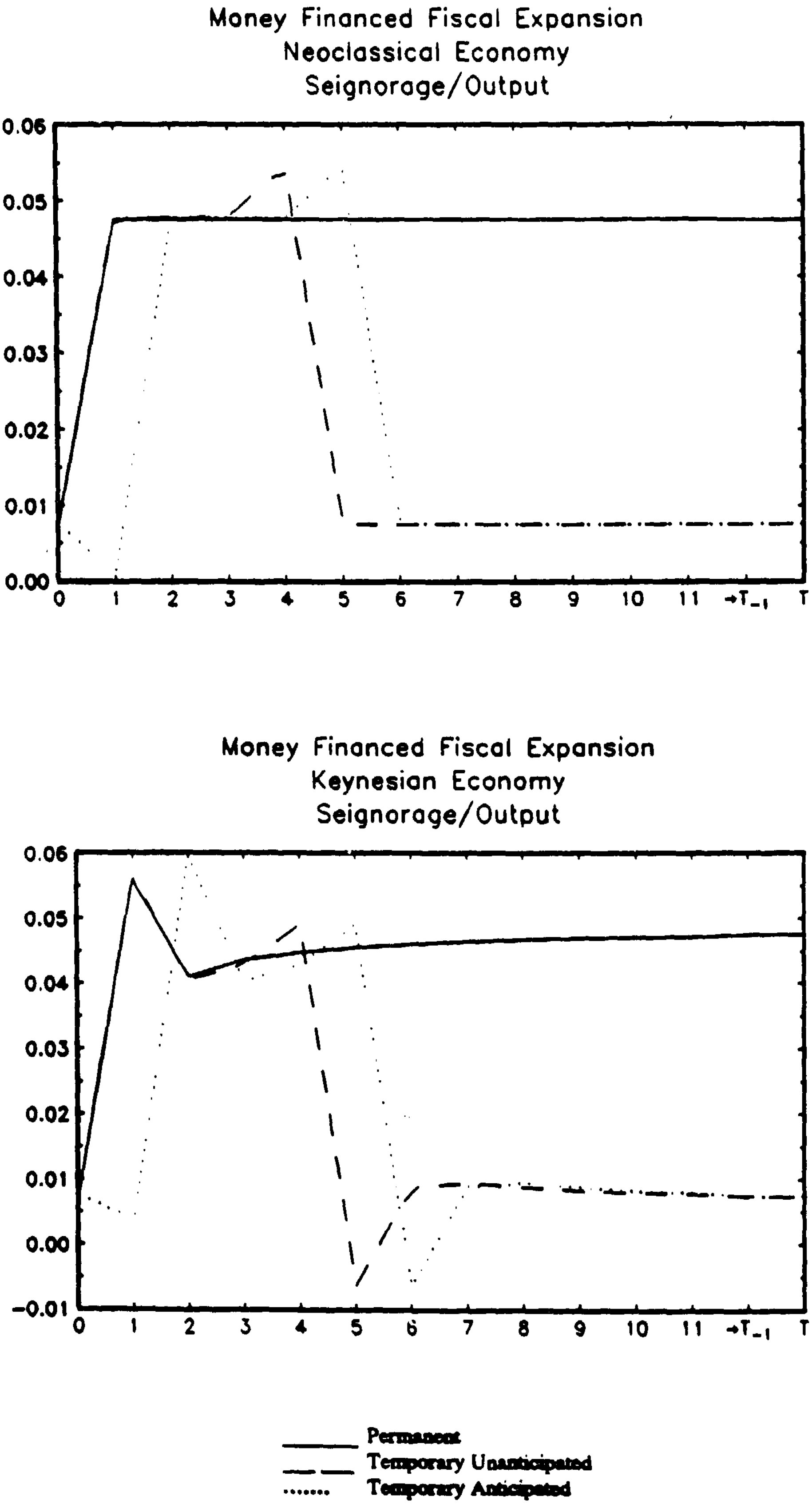
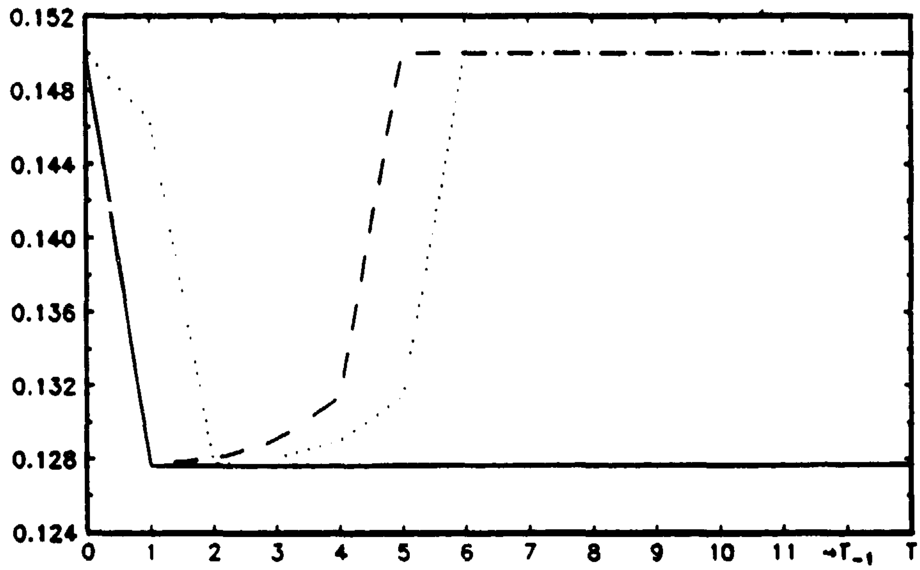
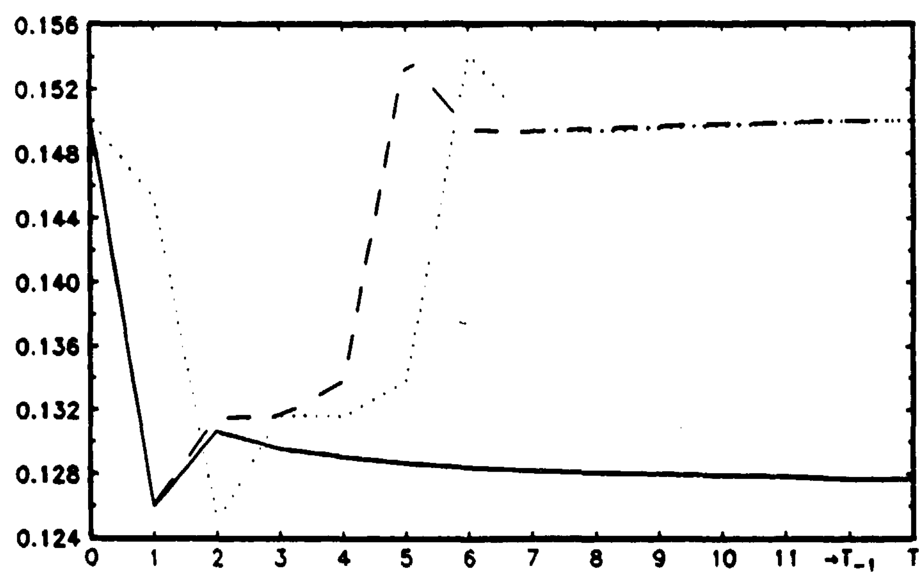

Money Financed Fiscal Expansion
Neoclassical Economy
Seignorage/Output
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0
1
2
3
4
5
6
7
8
9
10
11
→T₋₁
T
Money Financed Fiscal Expansion
Keynesian Economy
Seignorage/Output
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
0
1
2
3
4
5
6
7
8
9
10
11
→T₋₁
T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 14

Money Financed Fiscal Expansion
Neoclassical Economy
Money/Output



Money Financed Fiscal Expansion
Keynesian Economy
Money/Output



______ Permanent
_ _ _ Temporary Unanticipated
.... Temporary Anticipated

Figure 15

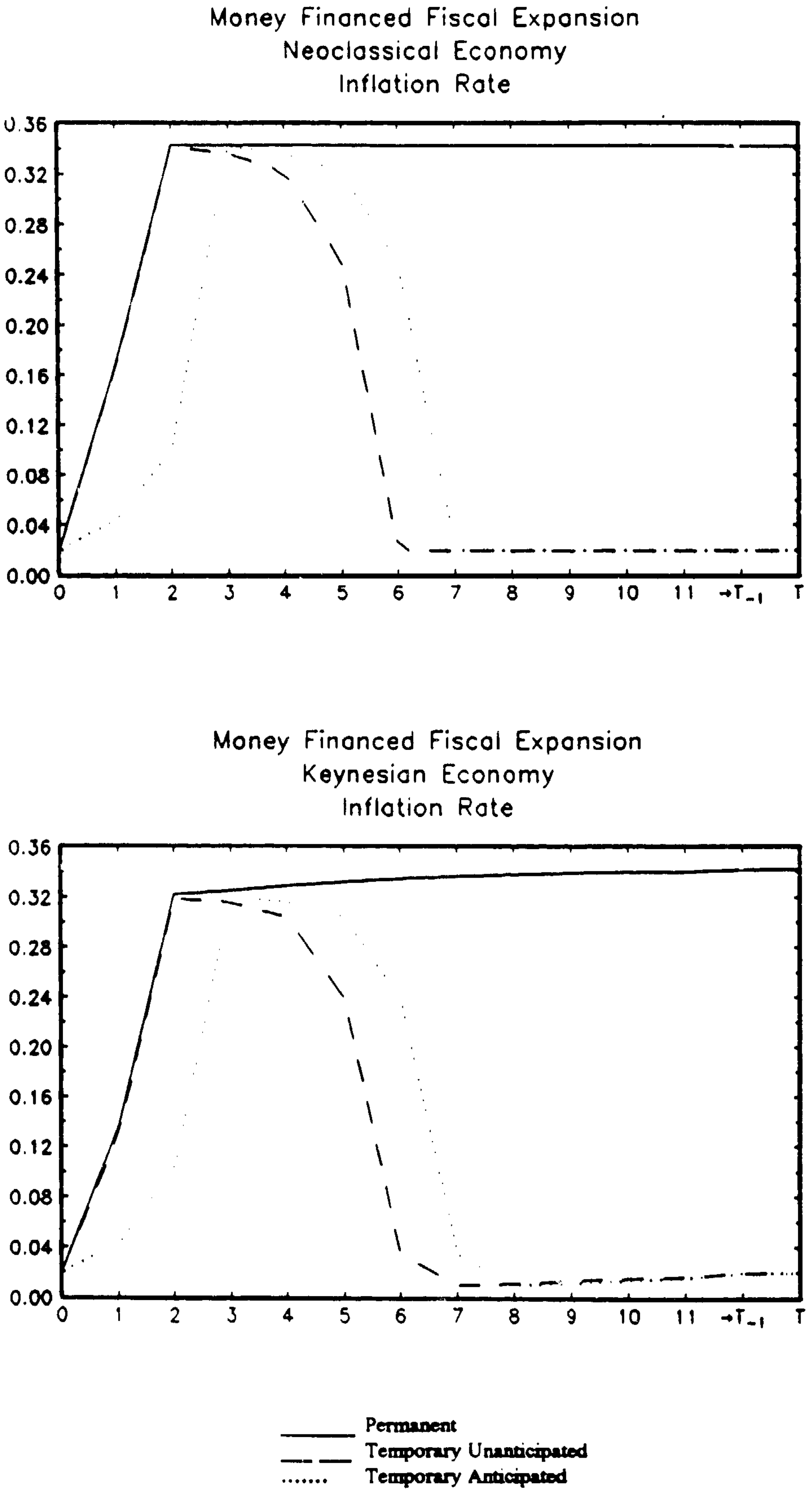

Money Financed Fiscal Expansion
Neoclassical Economy
Inflation Rate
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T
Money Financed Fiscal Expansion
Keynesian Economy
Inflation Rate
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 16

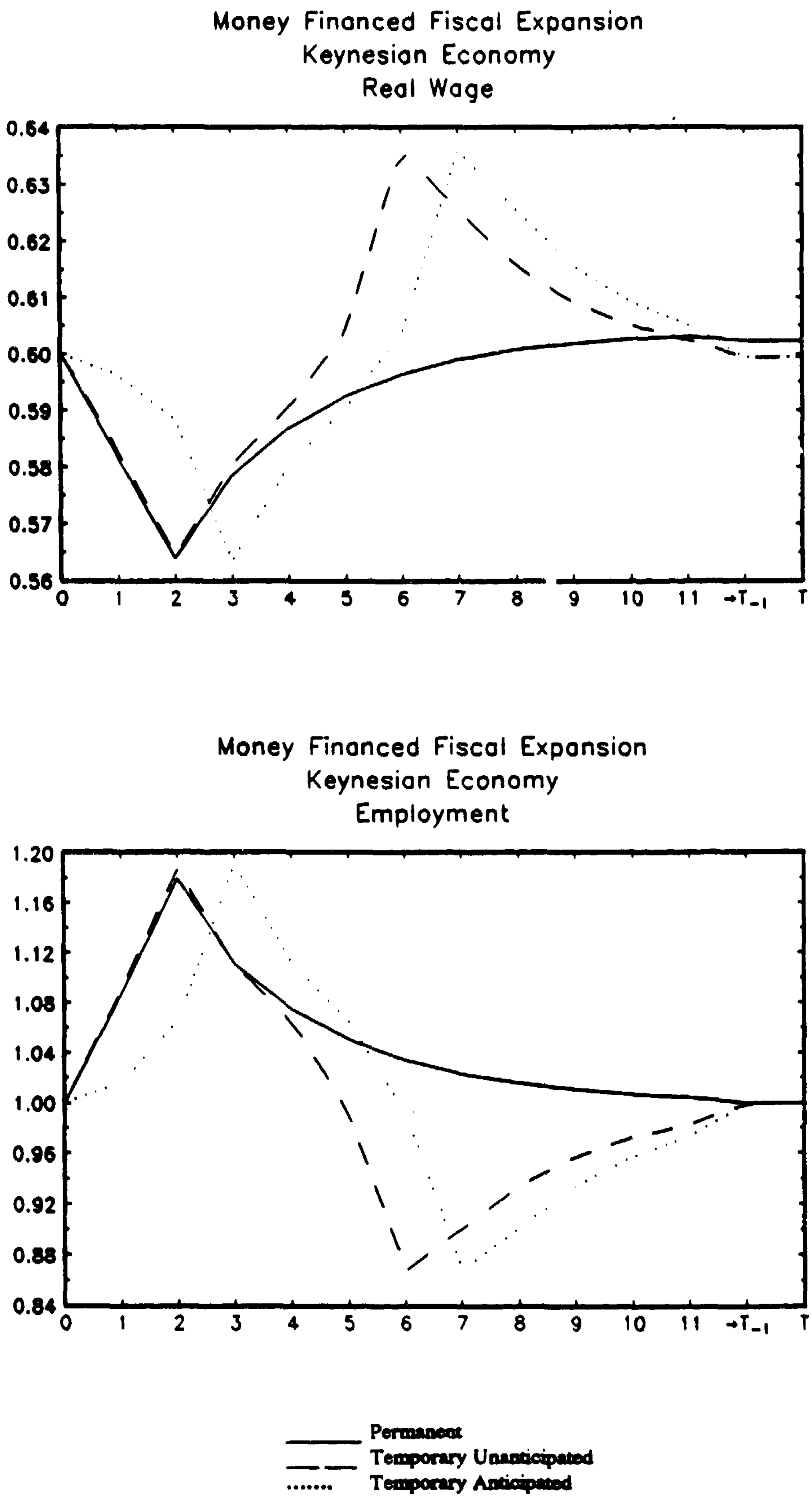

Money Financed Fiscal Expansion
Keynesian Economy
Real Wage
0.64
0.63
0.62
0.61
0.60
0.59
0.58
0.57
0.56
0
1
2
3
4
5
6
7
8
9
10
11
→T₋₁
T
Money Financed Fiscal Expansion
Keynesian Economy
Employment
1.20
1.16
1.12
1.08
1.04
1.00
0.96
0.92
0.88
0.84
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 17

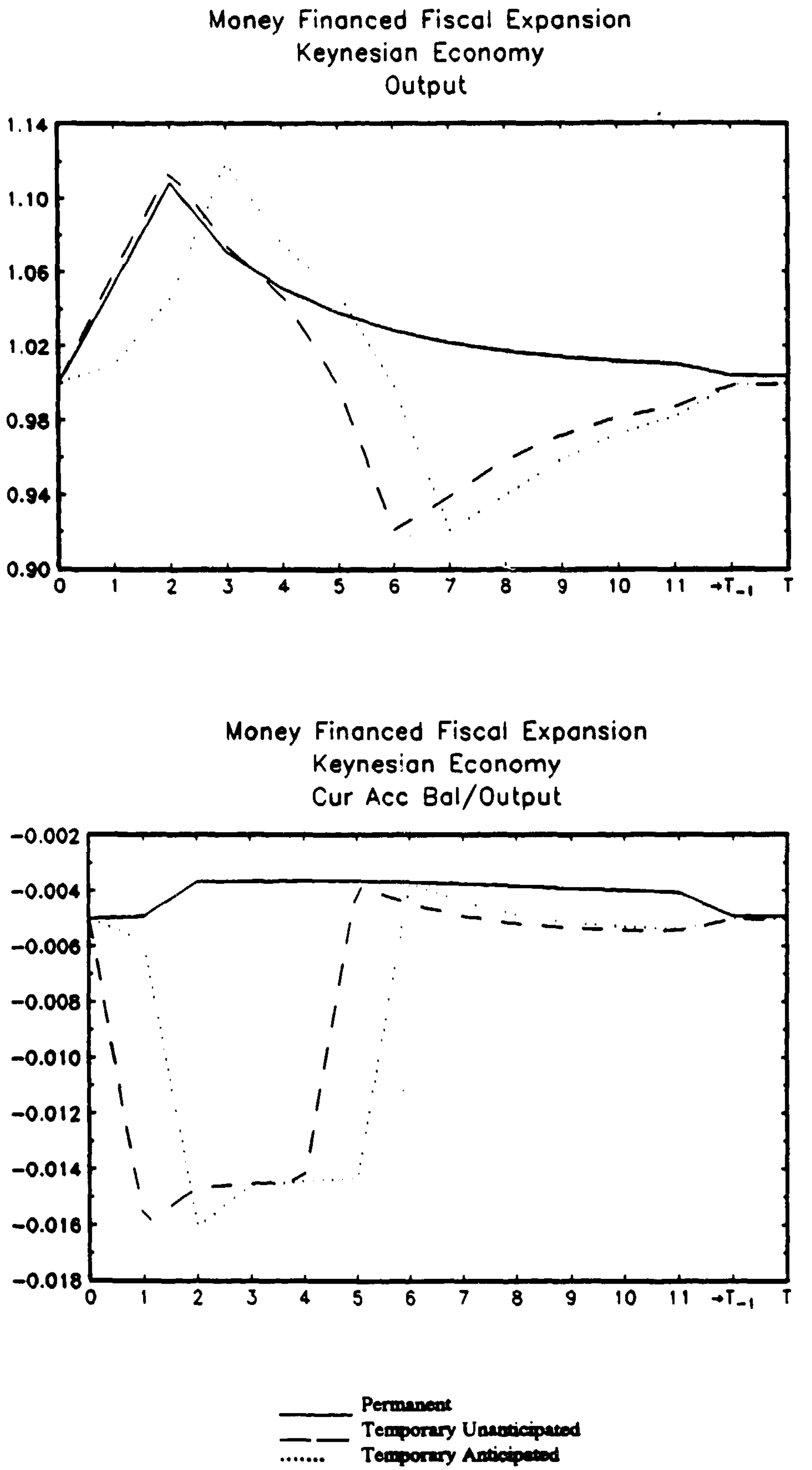
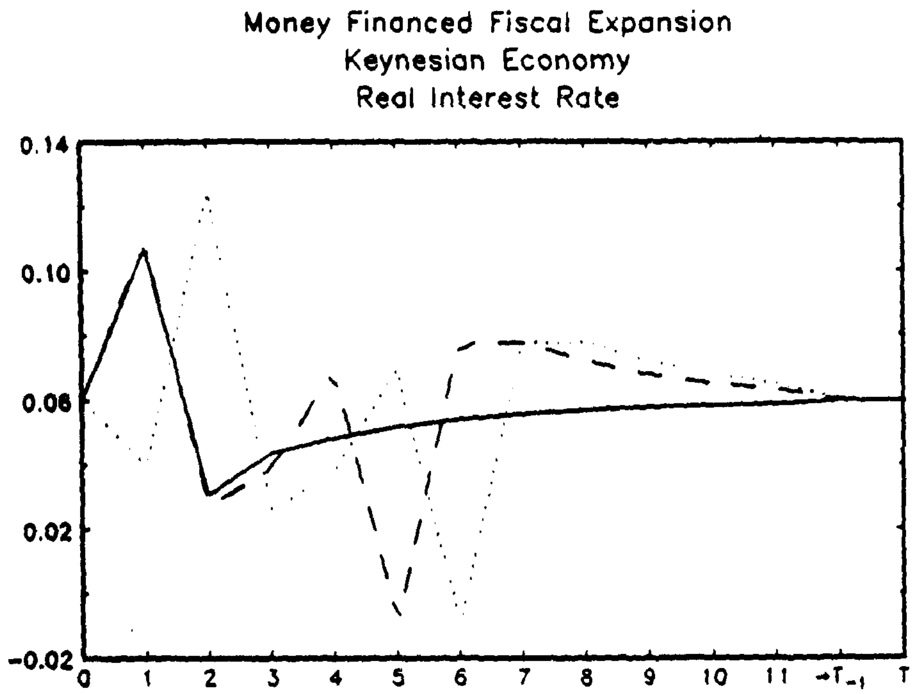
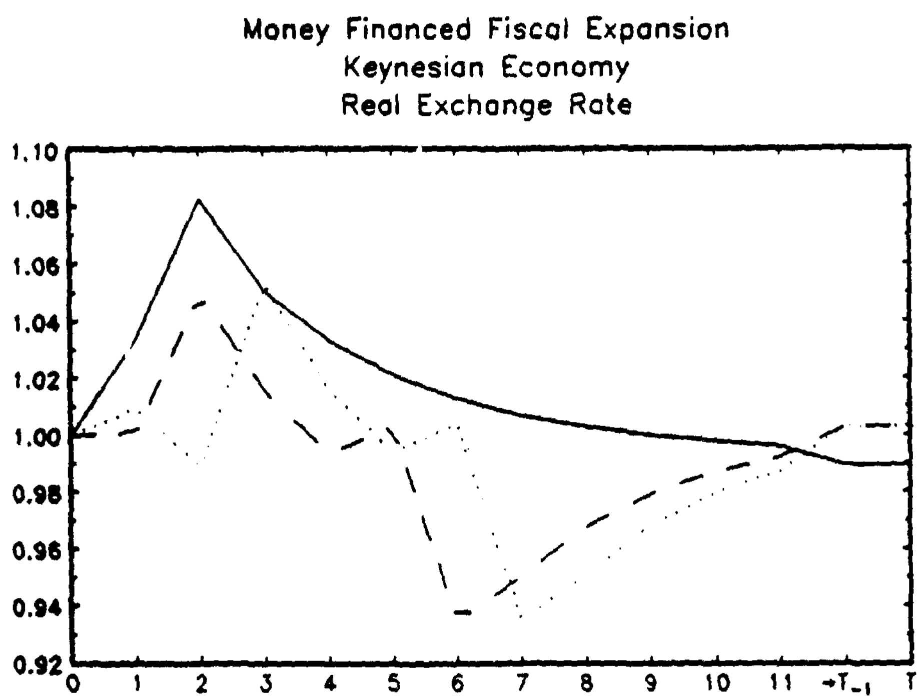

Money Financed Fiscal Expansion
Keynesian Economy
Output
1.14
1.10
1.06
1.02
0.98
0.94
0.90
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T
Money Financed Fiscal Expansion
Keynesian Economy
Cur Acc Bal/Output
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
-0.014
-0.016
-0.018
0 1 2 3 4 5 6 7 8 9 10 11 →T₋₁ T
Permanent
Temporary Unanticipated
Temporary Anticipated

Figure 18





Permanent
Temporary Unanticipated
Temporary Anticipated

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